



COMPREHENSIVE STUCK PIPE COURSE

Cause, Solutions & Prevention

November,

Suez Canal Univ. – SPE student chapter



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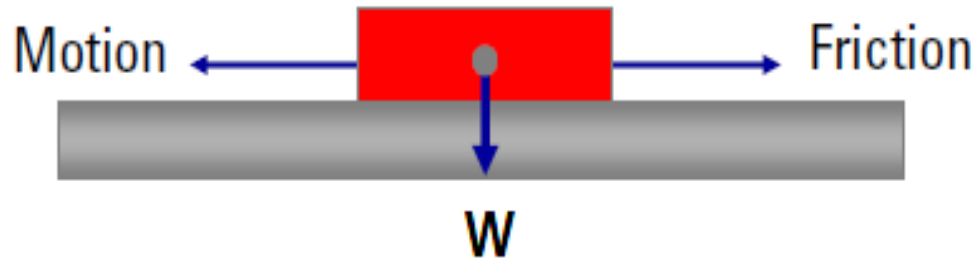


Introduction - Basic knowledge

Introduction – Basic knowledge

Friction: The force resulting from the movement of one element against another.
Direction of friction is opposite to the direction of movement

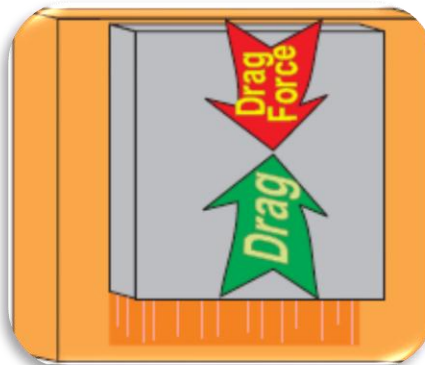
Friction can be called Drag forces



Introduction – Basic knowledge



Torque: The force to rotate the string in the well bore. Torque is measured in unit of force by length (ft.lbf)



Drag: The axial resistance opposite to the pipe movement, it is generated due to the interaction between the string (DS or Csg) and formation.

The drag is normally measured in terms of pound force (lbf)

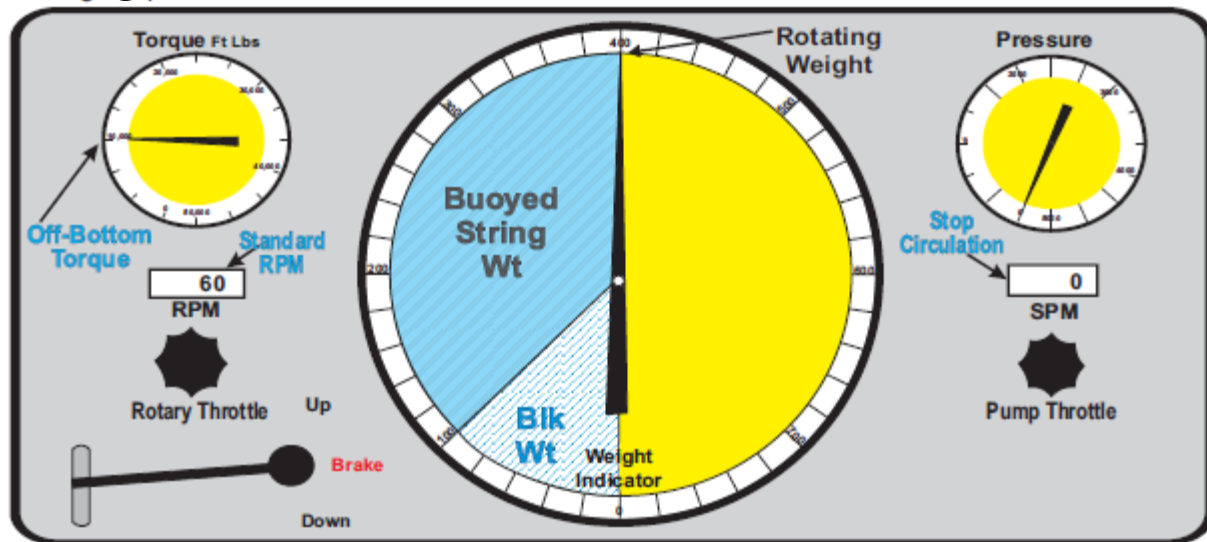
Introduction – Basic knowledge

Rotating weight: The weight indicator reading which includes the travelling equipment weight and the drag free buoyed weight of the drill string suspended by the blocks.

Off BTM torque: The torque required to rotate the drill string at a standard RPM without drilling torque.

Introduction – Basic knowledge

Recording off BTM torque & Rotating weight



1. Position the bit +/-20' from bottom.
2. Stop the pumps.
3. Slowly increase rotation to a pre-selected standard RPM (i.e., 60 RPM).
4. When the torque gauge stabilizes, record *Off-Bottom Torque*.
5. When the Weight Indicator stabilizes, record *Rotating Weight*.

Introduction – Basic knowledge

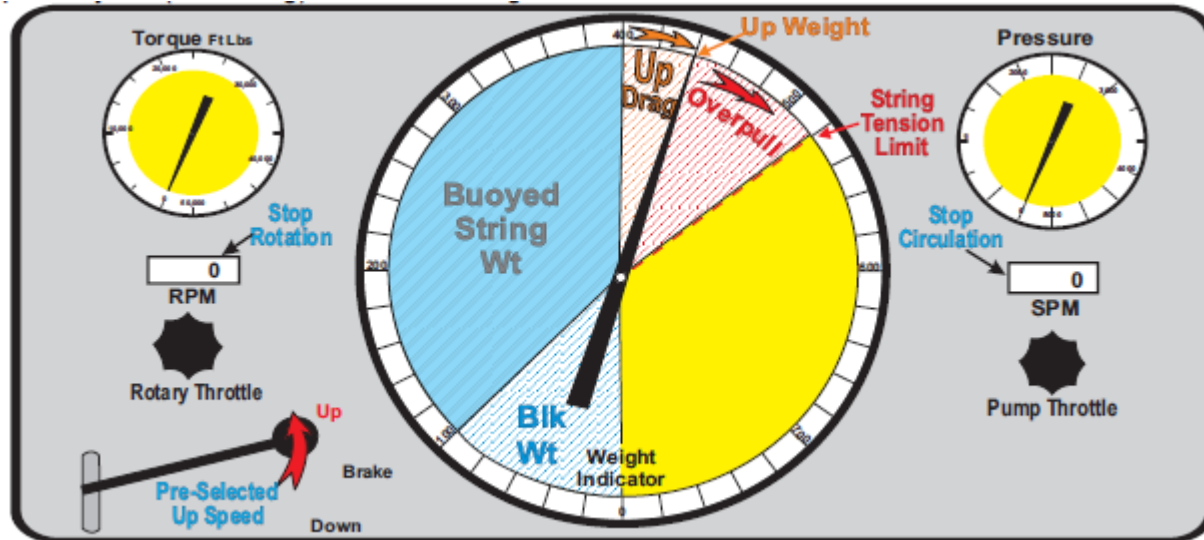
Up weight: The weight indicator reading required to raise the drillstring at a standard speed without rotation and circulation

* Up weight – Rotating weight = Up drag

String tension limit: The maximum safe weight indicator reading with no torque to avoid plastic yield (Stretching) of the drillstring.

Introduction – Basic knowledge

Recording Up weight



1. Stop rotation.
2. Do not circulate.
3. Raise the string at a pre-selected standard speed, (i.e., 45' per minute).
4. When the Weight Indicator stabilizes, record **Up Weight**.

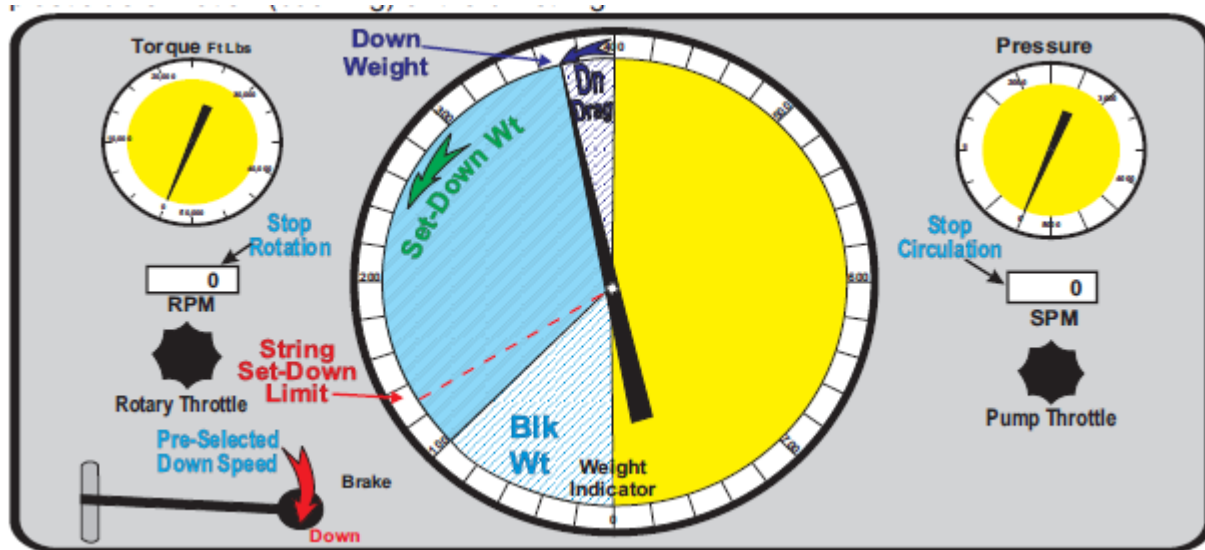
Introduction – Basic knowledge

Down weight: The weight indicator reading required to lower the drillstring at a standard speed without rotation and circulation

String set down limit: The minimum safe weight indicator reading with no torque to avoid plastic deformation (buckling) of the drillstring.

Introduction – Basic knowledge

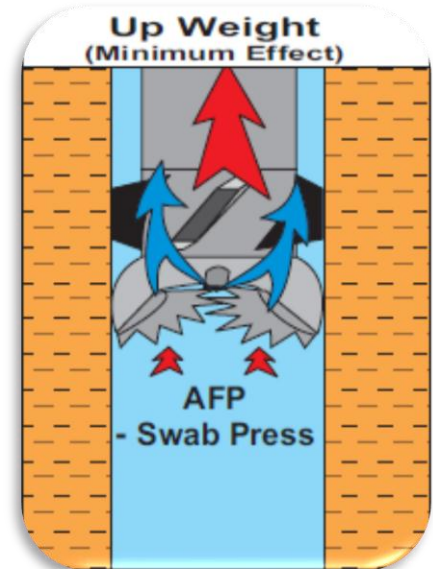
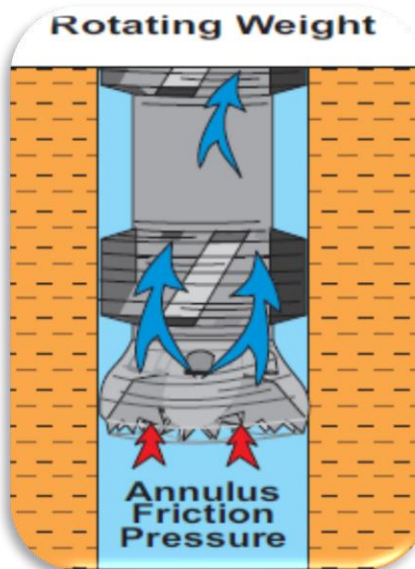
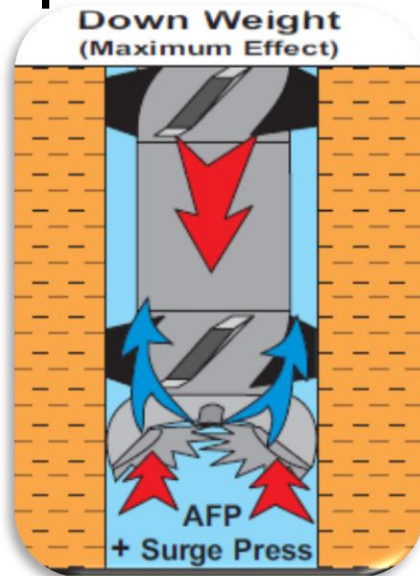
Recording Down weight



1. Do not rotate.
2. Do not circulate.
3. Lower the string at a pre-selected standard speed, (i.e., 2 minutes per stand).
4. When the Weight Indicator stabilizes, record *Down Weight*.

Introduction – Basic knowledge

Effect of circulating pressure

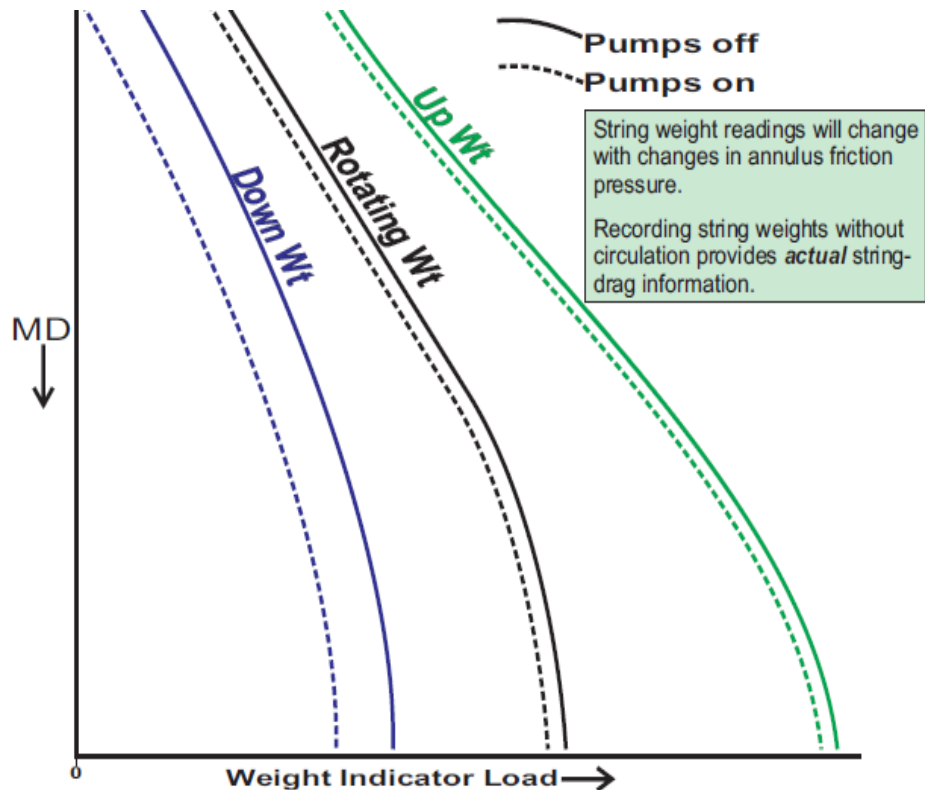


Introduction – Basic knowledge

Effect of circulating pressure

Stop circulation when recording string weight data

Recording string weights without circulation provides actual string drag information.



[illegible]



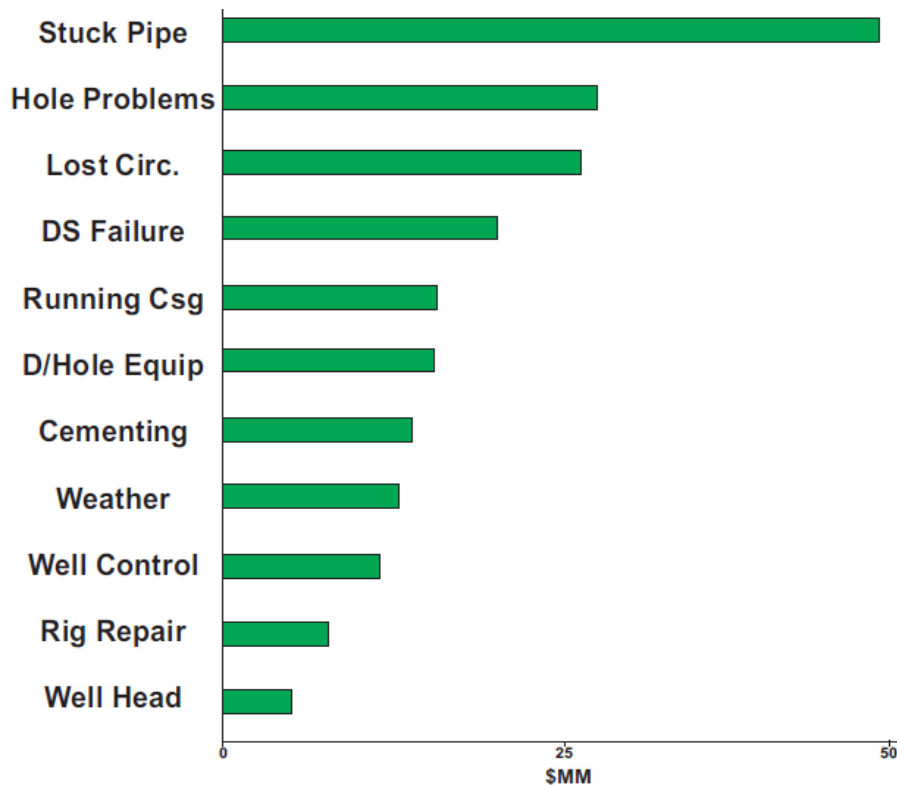
Introduction – Stuck pipe

Introduction – Stuck pipe

Stuck pipe: An interruption in planned operations as excessive drag forces prevent pulling the drillstring out of the hole.

Tight hole: A momentary interruption in planned operations as high drag forces restrict drillstring movement above normal operating conditions. The pipe is not stuck in the hole as acceptable progress is still being made.

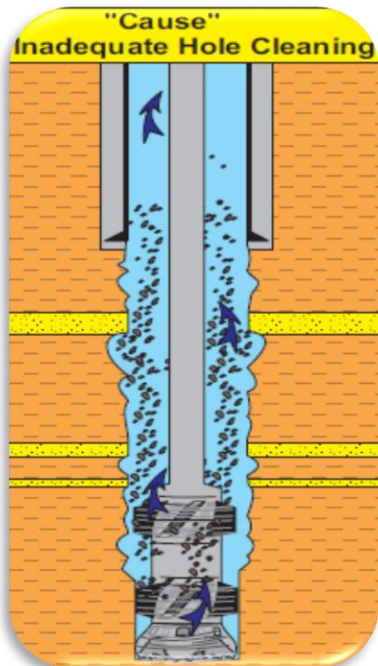
Introduction – Stuck pipe



Stuck pipe statistics

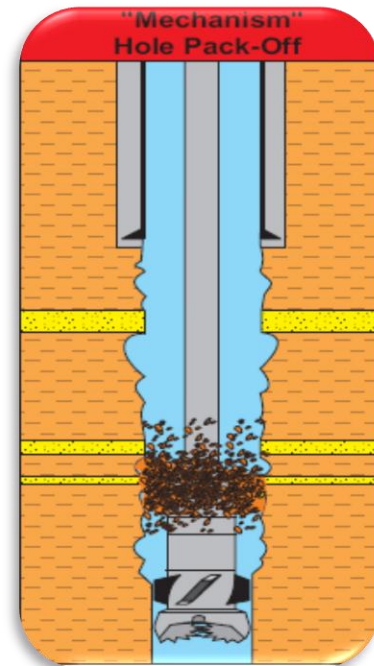
Industry statistics gathered since 1989 show the relative cost of non-productive time. Stuck pipe is still the drilling industry's most costly unscheduled event.

Introduction – Stuck pipe



Cause: The condition(s) responsible for the sticking mechanism.
There are +20 causes of stuck pipe.

Mechanism: The mechanical force sticking the drillstring in the hole.
There are only 3 mechanisms of stuck pipe.





Stuck pipe mechanisms

Stuck pipe mechanisms

**Stuck pipe
mechanism**

S

Hole pack off/Bridge

Differential

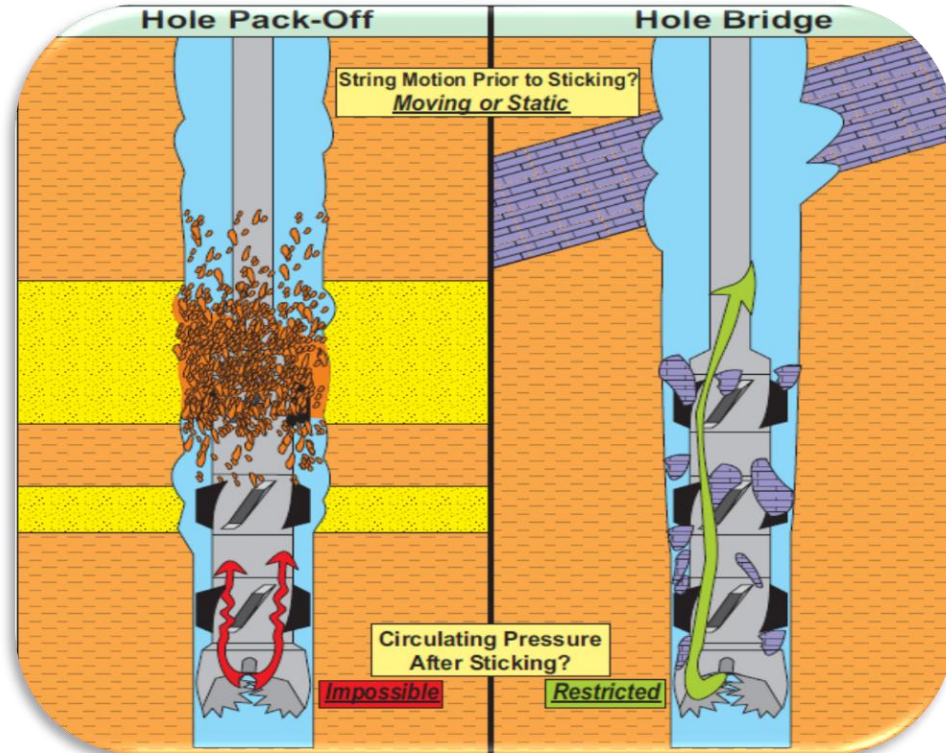
Well bore geometry

Stuck pipe mechanisms

Hole pack off/Bridge

Pack off: Small pieces of formation, cement or junk settle around the drillstring preventing circulation with no string movement likely.

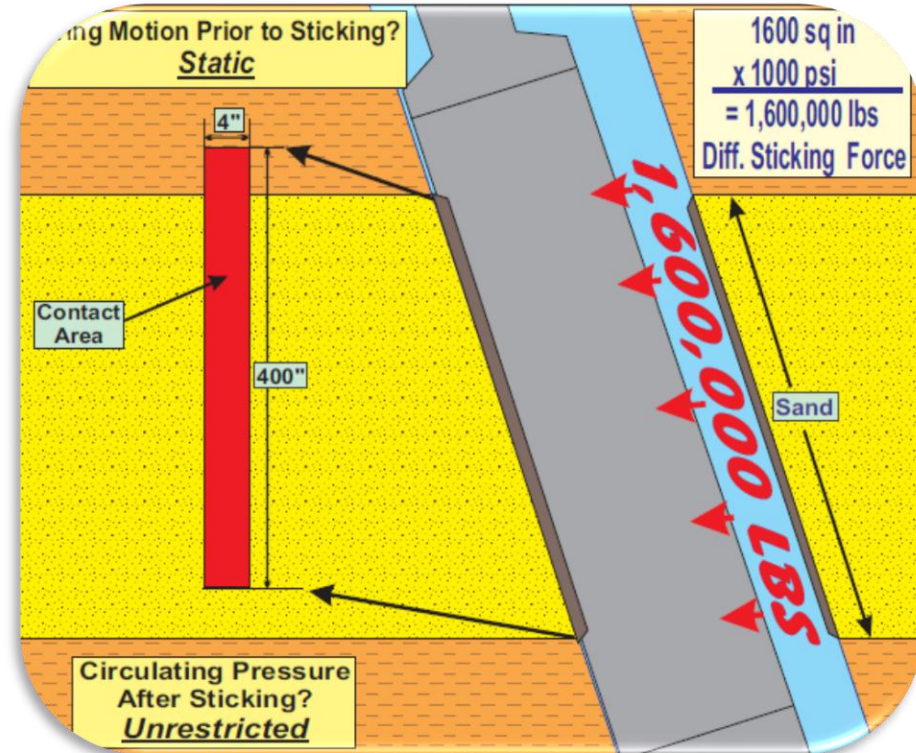
Bridge: Medium to large pieces of formation, cement or junk settle around the drillstring allowing restricted circulation with little to no string movement.



Stuck pipe mechanisms

Differential Sticking mechanism

Hydrostatic overbalance pressure drives the static drillstring into the thick filter cake of a permeable zone.



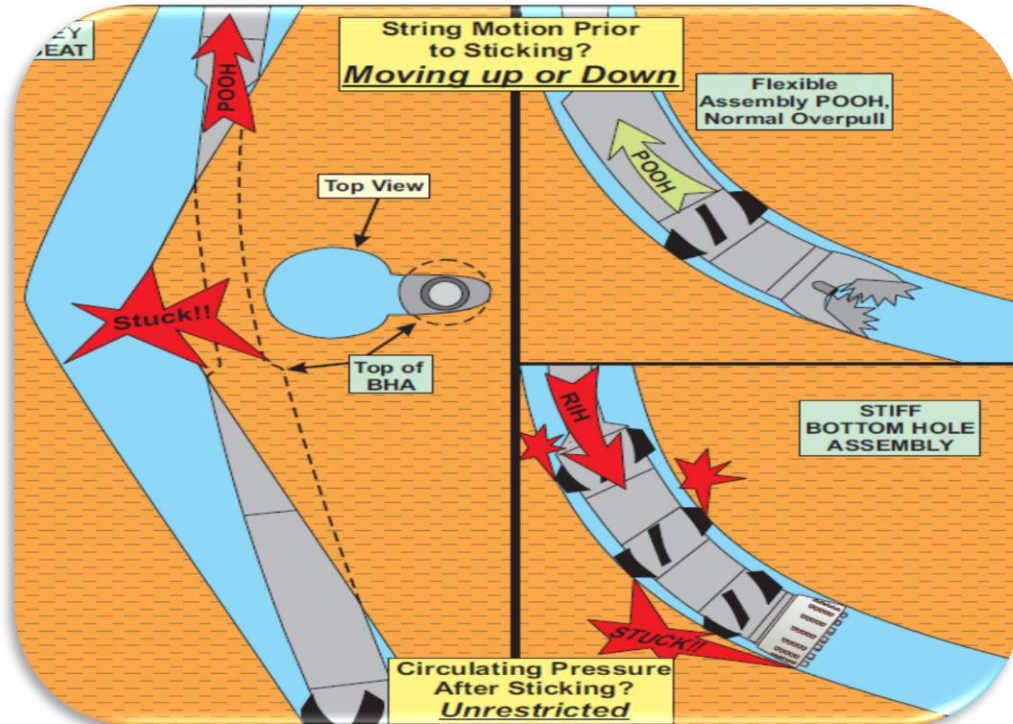
Stuck pipe mechanisms

Well bore geometry mechanism

Sharp changes in hole angle/direction; an undergauge hole diameter

or

increase in assembly stiffness will not allow passage of the string.



Stuck pipe mechanisms

STEP 1: DETERMINE THE STICKING MECHANISM

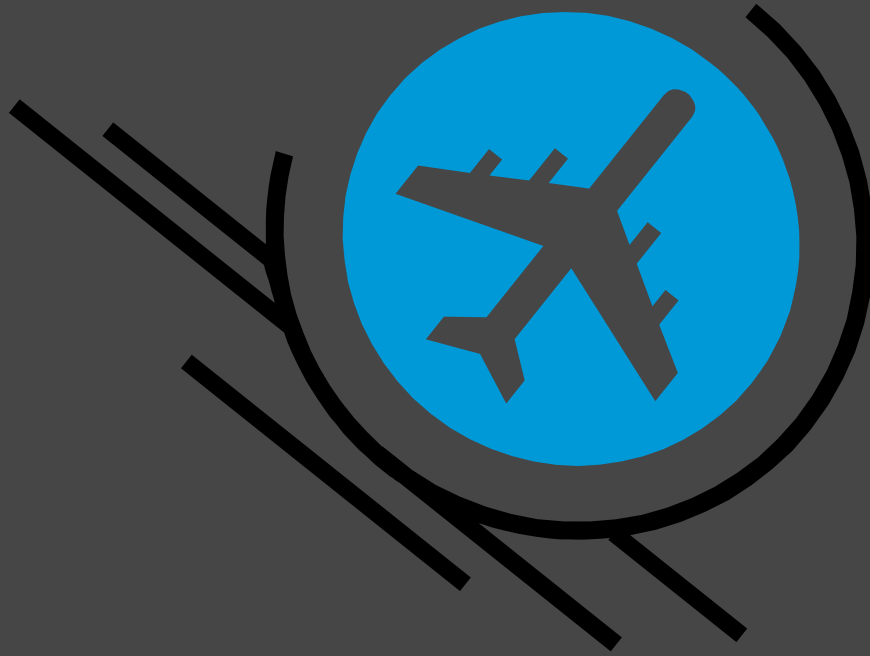
DESCRIBE THE STRING MOTION JUST BEFORE STICKING OCCURRED.		PACK-OFF	BRIDGE	DIFFERENTIAL	GEOMETRY
Circle the numbers in the row with the best description. Circle only 1 row of numbers.	Moving Up	1	1	0	1
	Back Reaming	1	1	0	1
	Rotating Only	1	1	0	0
	Moving Down	1	1	0	1
Pipe Static or Slide Drilling		1	1	1	0
Reaming Down or Rotary Drilling		1	1	0	1
DESCRIBE THE CHANGE IN CIRCULATING PRESSURE JUST AFTER STICKING OCCURRED.					
No Change in Circulating Pressure		0	0	1	1
Circulation is Possible But Restricted and Possibly Fluctuating		0	1	0	0
Stalled Motor Pressure. Pressure Increases With Rotation		0	0	0	1
Circulation is Impossible		1	0	0	0
Add the columns of circled numbers. The column with the sum of "2" determines the sticking mechanism.					
Totals =					

Stuck pipe mechanisms



Stuck pipe mechanism determination

Exercises



Stuck pipe Causes

Stuck pipe causes – Pack off/Bridge

Inadequate hole

Well bore instability

Cement related

Special

Settled cuttings

Geo-pressurized shale
Hydro-charged shale
Reactive shale
Overburden/tectonic stresses
Unconsolidated /fractured
formations

Cement failure
Soft cement

Junk in hole

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

The inability to efficiently remove formation solids (cuttings, cavings) from the wellbore.

0 – 40 degree holes

> 40 degree
holes

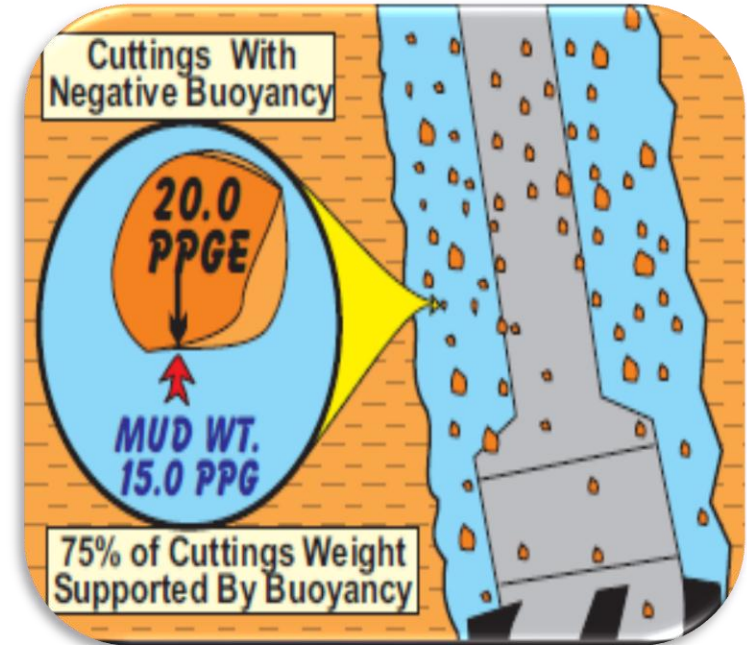
Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

0 – 40 degree holes

Force of Fluid Buoyancy :

- The lifting force generated by the difference between cuttings density and fluid density.
- Heavier mud weight exhibits better hole cleaning efficiency due to greater buoyancy.
- Buoyancy is the greatest contributor (40%>) to the total force pushing the cuttings out of the hole.



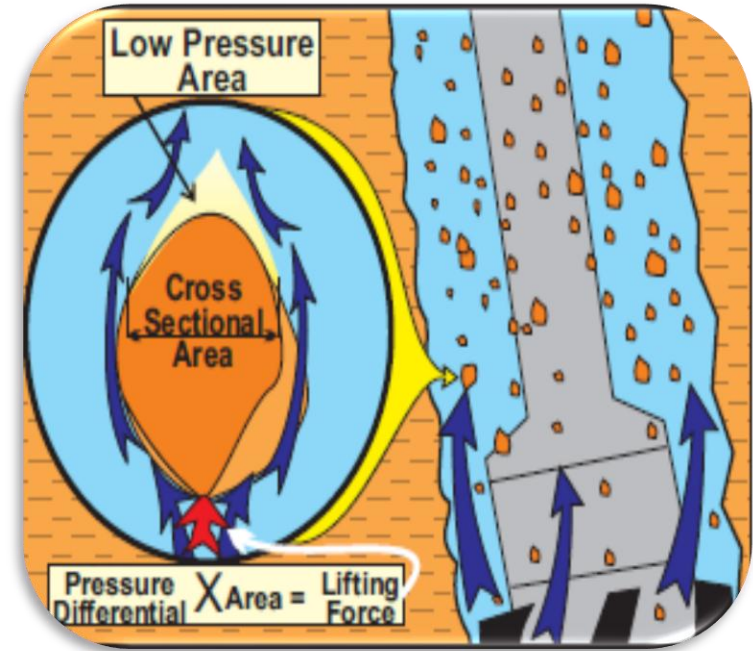
Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

0 – 40 degree holes

Force of Annular Velocity:

- The lifting force generated by the velocity of the fluid slipping by the cuttings (slip velocity).
- Higher annular velocity exhibits better hole cleaning efficiency due to greater pressure drop across the cutting.
- Annular velocity is the second greatest contributor to the total force pushing the cuttings



Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

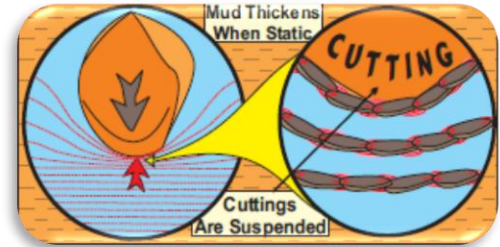
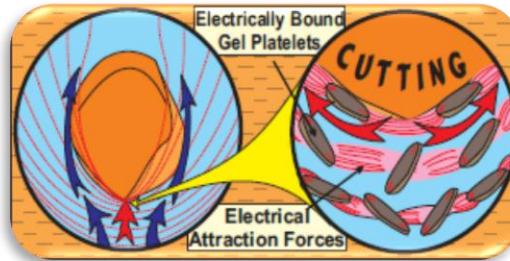
0 – 40 degree holes

Carrying Capacity of Yield Point:

- The lifting force generated by over coming the electrical attraction of the active mud solids(gel).
- Higher YP exhibits better hole cleaning efficiency (near vertical hole) due to the higher attraction forces between the gel platelets.

Suspension Capacity of Gel Strength:

- The ability of mud to thicken when static and to become more fluid when agitated (thixotropic).
- When circulation is stopped, the electrical strength of the gels reduces the *settling velocity* of the solids.



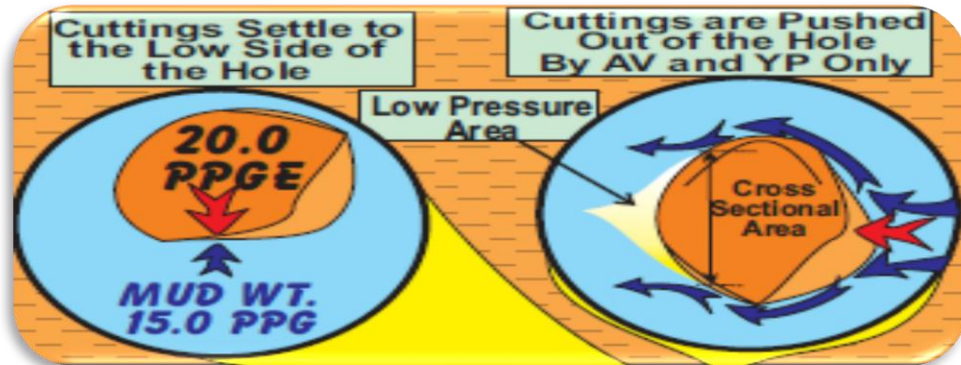
Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

> 40 degree holes

Assistance of Fluid Buoyancy is Lost :

In high angle holes, the force of buoyancy provides *less assistance in pushing the cuttings* out of the hole.



Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

> 40 degree holes

Force From Annular Velocity and YP (LSYP):

The forces generated from AV and YP push the cuttings out of the hole in a "tumbling" motion

(much like wind blowing leaves across the yard). When circulation is stopped, the cuttings sink

to the low side of the hole forming a ***stable cuttings bed (does not slide back down the hole)*** in the horizontal section

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

> 40 degree holes

Force From Annular Velocity and YP (LSYP):

The forces from AV and YP push the cuttings out of the hole in a "short hopping" motion. Cuttings accumulate on the low side of the hole forming an ***unstable cuttings bed (slides down hole even while circulating)***.

Fluid circulation is displaced to the top side of the hole by the higher density cuttings bed settling to the low side. When circulation is stopped, the bed of cuttings avalanche down hole, eventually stabilizing at +/-65 **hole angle**.

40 : 65 degree section “Boycott effect”

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Hole cleaning pills

Proper use of mud pills will improve hole cleaning and the pill volume should be determined based on the hole size and the calculated effect on hydrostatic head

17 ¹ / ₂ " and 16" Intervals	12 ¹ / ₄ " Intervals	8 ¹ / ₂ " Intervals
50 + bbl	30 - 50 bbl	20 bbl

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Hole cleaning pills

High viscosity pills

- A highly viscous pill will be effective at sweeping cuttings out of a vertical hole
- The use of a viscous pill to clean deviated wells is not recommended

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Hole cleaning pills

Low viscosity pills

- A low viscosity pill will help to lift and remove a cuttings bed by the effect of turbulent flow.
- It will not be able to carry the cuttings up a vertical section of the hole or suspend the cuttings when the pumps are stopped

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Hole cleaning pills

**Low viscosity/High viscosity pills
“Tandem Pill”**

The concept is that the low viscosity pill stirs up the cuttings from the low side of the hole and the high viscosity pill sweeps them out of the hole

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Hole cleaning pills

**Low viscosity/Weighted pills
“Tandem Pill”**

The concept is that the low viscosity pill stirs up the cuttings from the low side of the hole and the weighted pill sweeps them out of the hole

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Hole cleaning pills

Weighted pills

- 2 to 3 ppg heavier than the mud
- This type of pill will aid hole cleaning by increasing the buoyancy of cuttings slightly

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

**Drillstring
rotation/Reciprocation**

As flow rate alone cannot always remove a cuttings bed, reciprocation and rotating of the drill pipe are advised whenever the hole is being circulated clean. This action will dramatically increase the erosion of cuttings beds in highly deviated wells

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Recommended drilling parameters

HOLE SIZE	MAX GPM	MIN GPM	BEST RPM	MIN RPM
17½"	900 – 1200	800 gpm, with ROP at 20 m/hr (65' / hr)	120 – 180	120
12¼"	800 – 1100	650-700 gpm, with ROP at 10-15m/hr (30-50' / hr) 800 gpm, with ROP at 20-30 m/hr (65-100' / hr)	150 – 180	120
9⅞"	700 – 900	500 gpm, with ROP at 10-20 m/hr (33-65' / hr)	120 – 150	100
8½"	450 – 600	350-400 gpm, with ROP at 10-20 m/hr (33-65' / hr)	70 – 100	60

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Circulation prior to connection or tripping out of hole

Before making a connection, the hole should be circulated at the normal flow rate to clear the cuttings from around the BHA. Depending upon the hole angle and the length of BHA, a circulation time of 5 to 10 min is often necessary

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

Circulation prior to connection or tripping out of hole

*Before tripping out , the hole should be circulated at the normal flow rate until the shakers are clean, whilst at the same time the drill pipe should be rotated at maximum speed / reciprocated. This may require up to 3 * bottom-ups, depending upon the hole angle and hole size*

Hole Angle	8 ¹ / ₂ "	12 ¹ / ₄ "	17 ¹ / ₂ "
0 - 10	1.3	1.3	1.5
10 - 30	1.4	1.4	1.7
30 - 60	1.6	1.8	2.5
60 +	1.7	2.0	3.0

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

0:40 degree holes
cleaning summary

Recommended practices

- High viscosity sweeps.
- High RPM required.
- High AV ($50 * \text{Hole diameter} = \text{GPM}$).
- Proper Mwt.
- Proper mud reology.

Stuck pipe causes – Pack off/Bridge

Inadequate hole cleaning

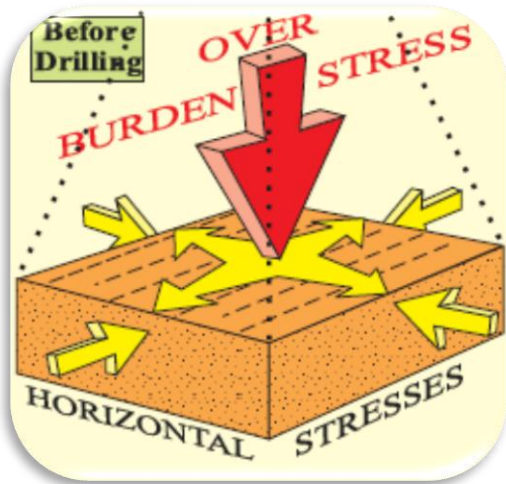
> 40 degree holes
cleaning summery

Recommended practices

- High density sweeps (-/+ 3 ppg) above Mud wt. required.
- High RPM required.
- High AV ($70 * \text{Hole diameter} = \text{GPM}$).
- Move up & down (Reciprocation) for cutting grinding in 40:65 degree for better hole cleaning with lighter cuttings.

Stuck pipe causes – Pack off/Bridge

Well bore instability



The mechanics of hole stability is based on the differential stresses imposed on the rock surrounding the wellbore

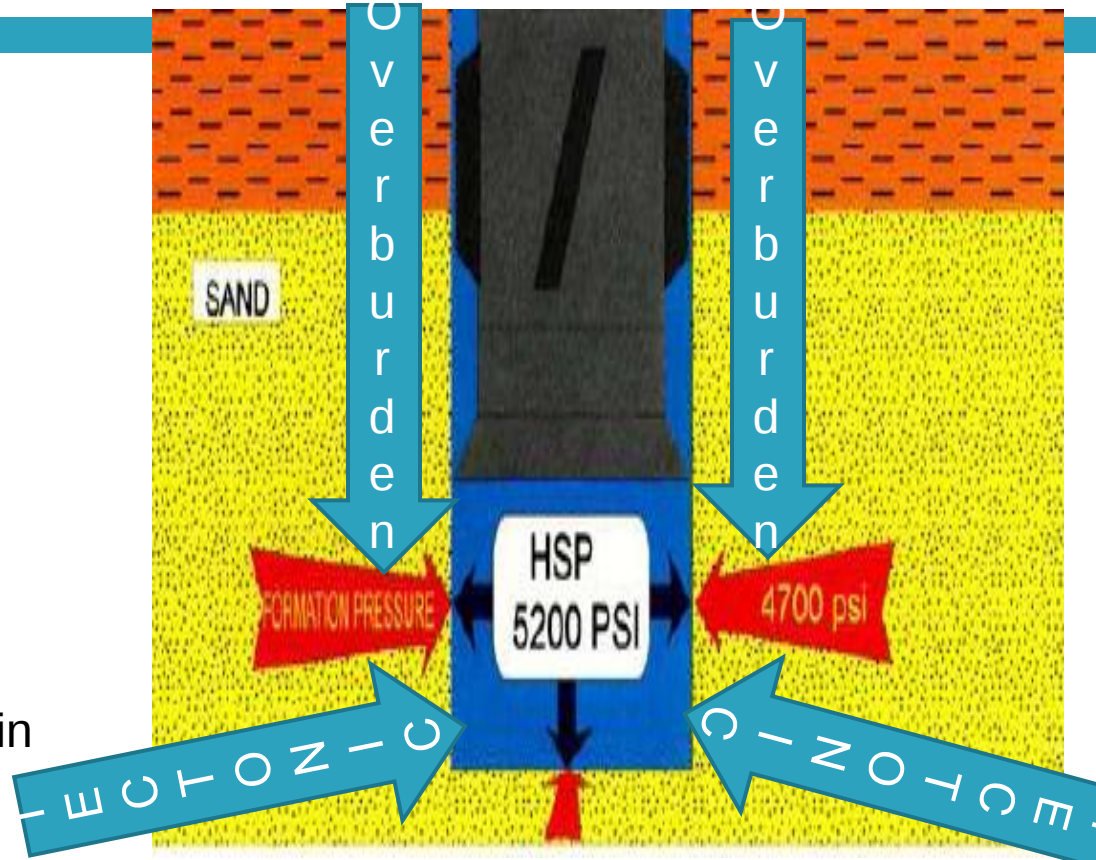
Stuck pipe causes – Pack off/Bridge

Well bore instability

Well bore stresses

Natural sources of rock stresses originated from overburden stresses, tectonic stresses & formation fluid pressure.

From here we can understand the main function of the drilling fluids; Wellbore stabilization.



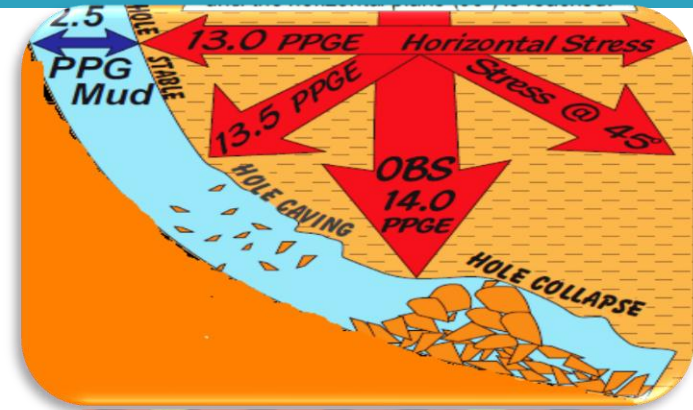
Stuck pipe causes – Pack off/Bridge

Well bore instability

Well bore stresses

Overburden stresses: Generated by the force of gravity of the combined weight of the rock and the formation fluids overlaying a depth of interest.

Tectonic stresses: Produced by lateral forces (side by side) in the



Stuck pipe causes – Pack off/Bridge

Well bore instability

Well bore stresses

Vertical to Horizontal stresses

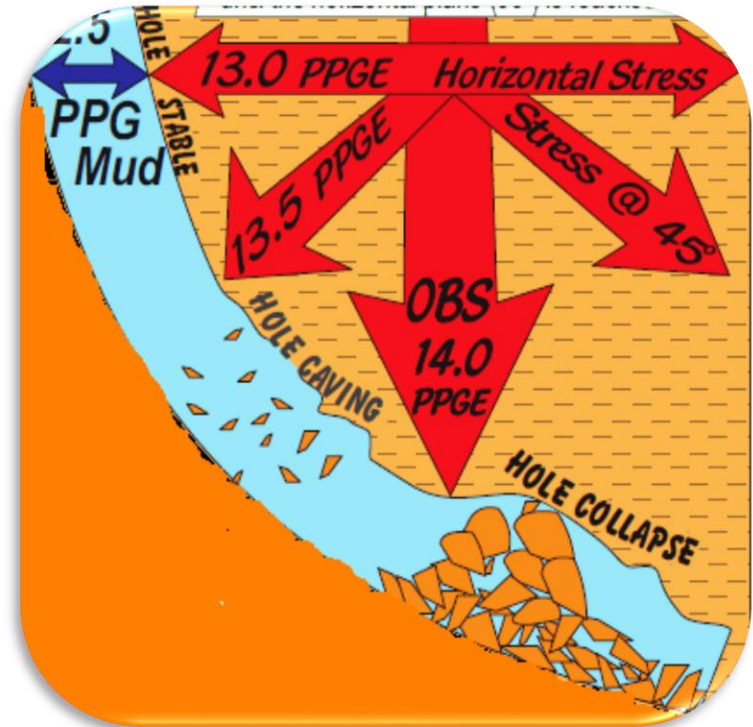
$V:H = \nu \text{ (Poisson's ratio)} / (1-\nu)$

For water in a cylinder

$\nu=0.5 \quad V:H = 1:1$

For shale in a cylinder

$\nu=0.45 \quad V:H = 1:0.8$



Stuck pipe causes – Pack off/Bridge

Well bore instability

Well bore stresses

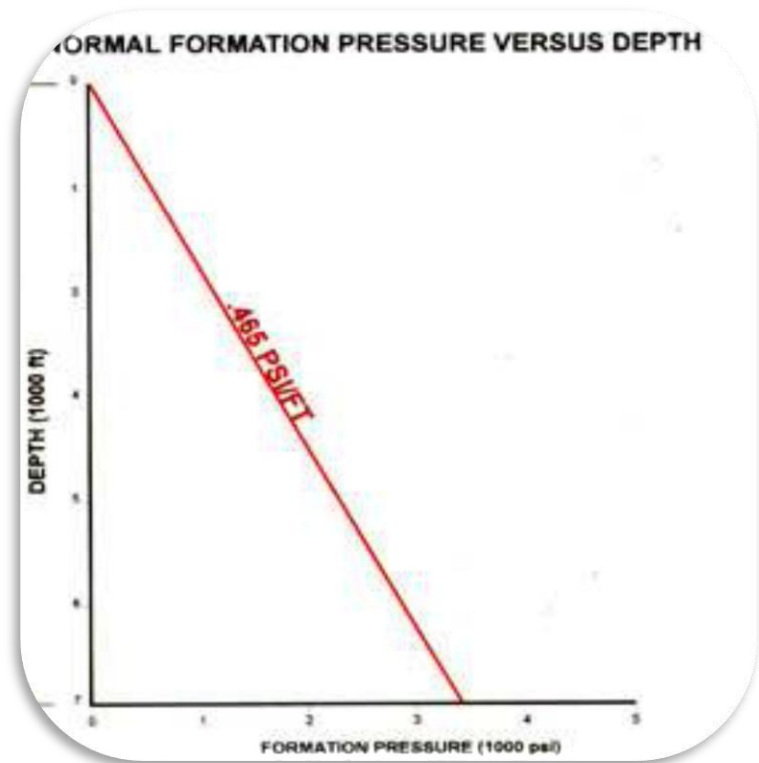
The pressure of the native fluids (Water , Oil, Gas) within the pore space of the rock.

Normal formation pressure:

Equals to a full column (From surface to depth of interest) of formation water.

Normal FP (psi)=

$0.465 \text{ (psi/ft)} * \text{TVD (ft)}$



Stuck pipe causes – Pack off/Bridge

Well bore instability

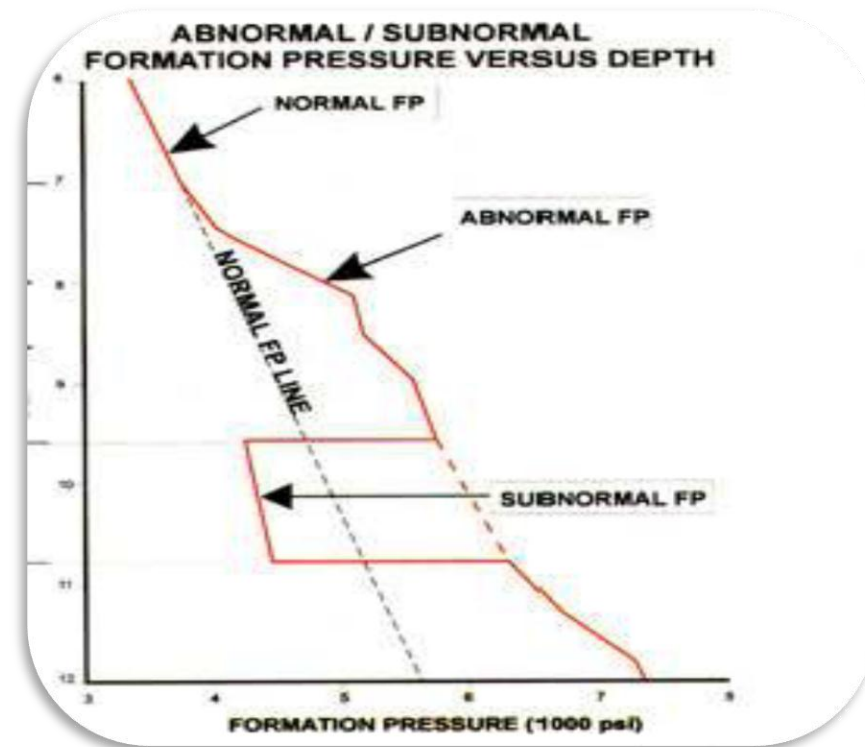
Well bore stresses

Abnormal: Greater than normal FP expected for depth of interest.

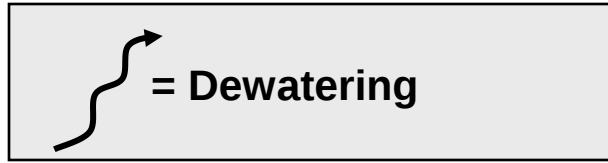
When permeability drops to near zero, formation fluids becomes trapped & any other compaction will pressurize the formation pressure over the normal.

Subnormal: Lower than normal.

May exist regarding production depletion

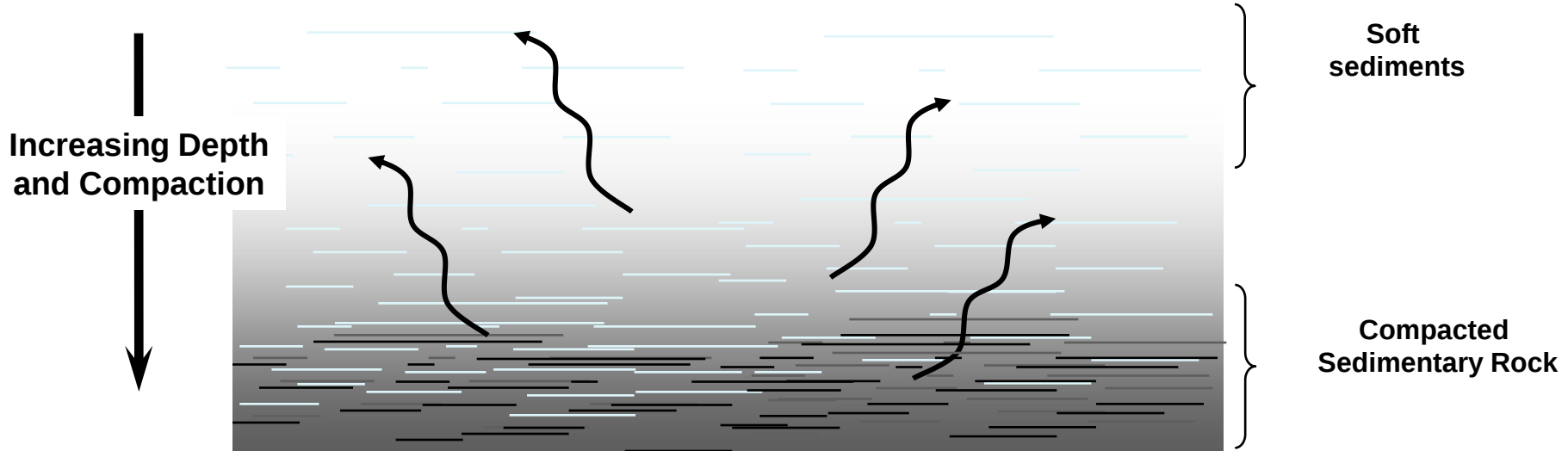


Stuck pipe causes – Pack off/Bridge



Well bore instability

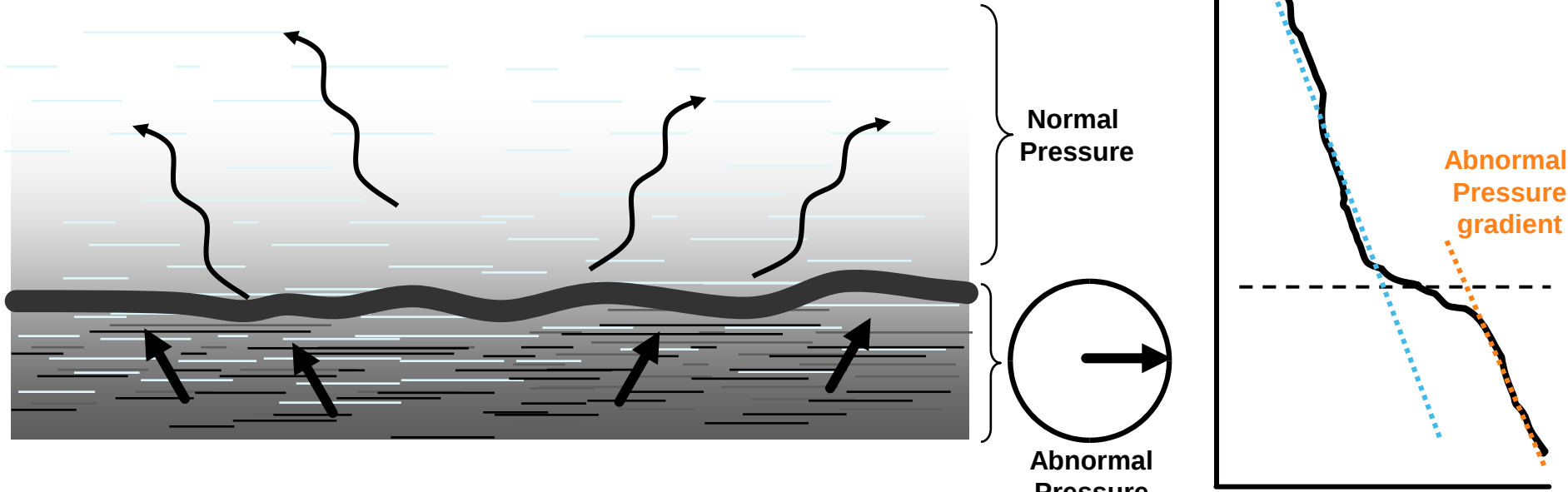
Well bore stresses



Stuck pipe causes – Pack off/Bridge

Well bore instability

Well bore stresses



Stuck pipe causes – Pack off/Bridge

Well bore instability

Well bore stresses

Mud HP: The pressure exerted on the wellbore regarding the drilling fluid column at a certain depth.

The mud hydrostatic pressure value should be between the formation fracture pressure and the formation pore pressure values.

$$HP(\text{psi}) = \text{Mwt (ppg)} \times .052 \times \text{TVD (ft)}$$

$$\text{- Pressure Gradient (psi/ft)} = \text{Mwt (ppg)} \times .052$$

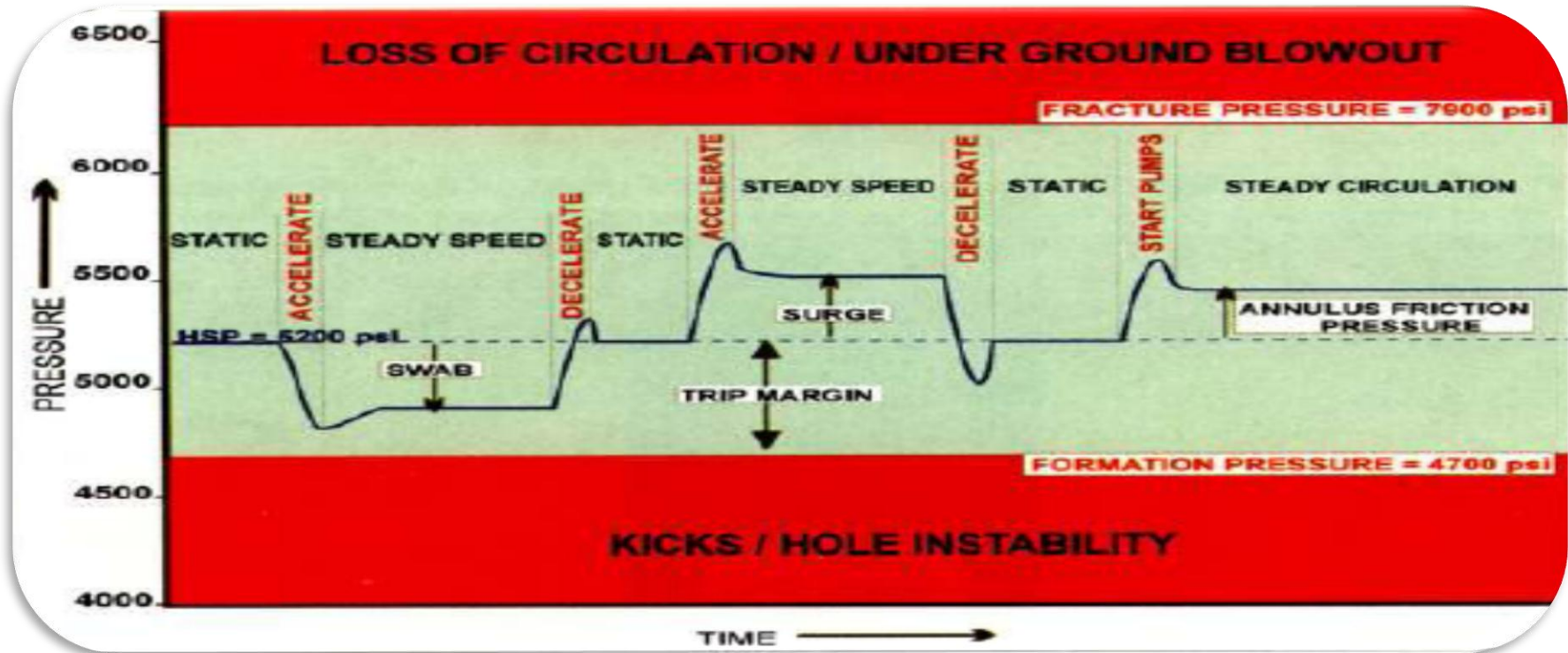
$$\text{- Pressure Gradient (psi/ft)} = \text{Pressure (psi)} \div \text{TVD (ft)}$$

$$\text{- Mwt (ppg)} = \text{Pressure Gradient} \div .052$$

$$\text{- Mwt (ppg)} = \text{HP (psi)} \div \text{TVD (ft)} \div .052$$

$$\text{TVD (ft)} = \text{HP (psi)} \div \text{Mwt (ppg)} \div 0.052$$

Stuck pipe causes – Pack off/Bridge



Stuck pipe causes – Pack off/Bridge

1-Well TVD = 8000 ft. Calculate Mud Hydrostatic pressure for each of the following Mud Weights.

14 ppg

12 ppg

11 ppg

2-What Mud Weight is required to give a pressure gradient of 0.59 psi/ft?

3-Mud Hydrostatic = 3900 psi at the bottom of an 8000 ft. TVD well. What would be the pressure gradient for the mud?

4-For question above what is the equivalent Mud Weight?

5-Pressure Gradient = 0.57 psi/ft. What is hydrostatic at 12000 ft. TVD?

Stuck pipe causes – Pack off/Bridge

1-Well TVD = 8000 ft. Calculate Mud Hydrostatic pressure for each of the following Mud Weights.

14 ppg

12 ppg

11 ppg

5824 psi

4992 psi

4576 psi

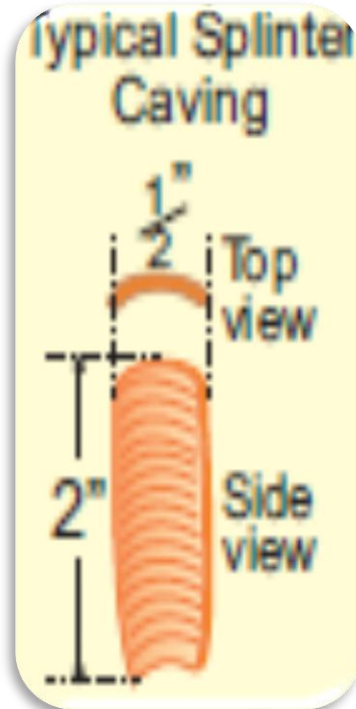
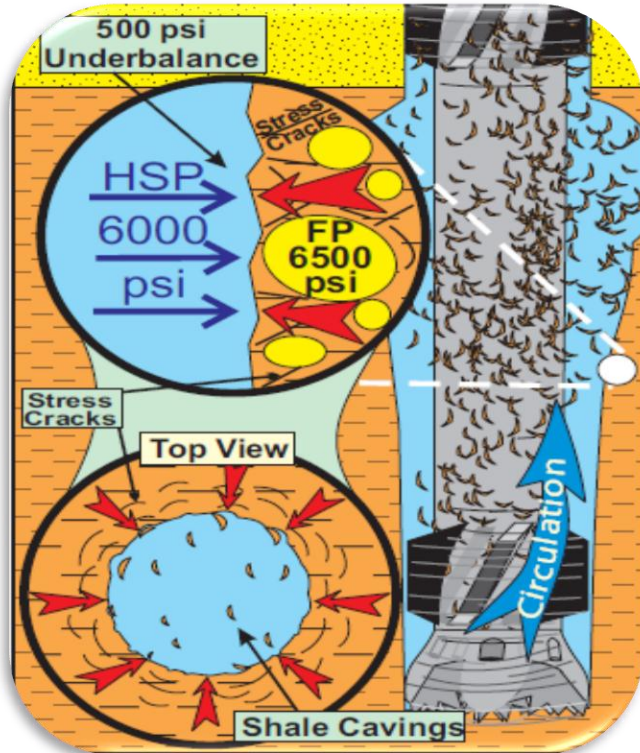
2-What Mud Weight is required to give a pressure gradient of 0.59 psi/ft? 11.4 ppg

3-Mud Hydrostatic = 3900 psi at the bottom of an 8000 ft. TVD well. What would be the pressure gradient for the mud? 0.49 psi/ft

4-For question above what is the equivalent Mud Weight? 9.4 ppg

5-Pressure Gradient = 0.57 psi/ft. What is hydrostatic at 12000 ft. TVD? 6840 psi

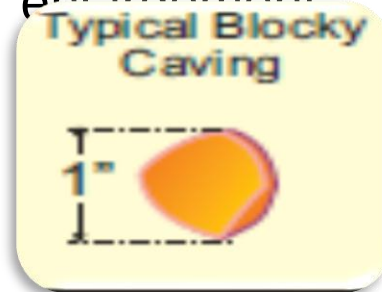
Stuck pipe causes – Pack off/Bridge



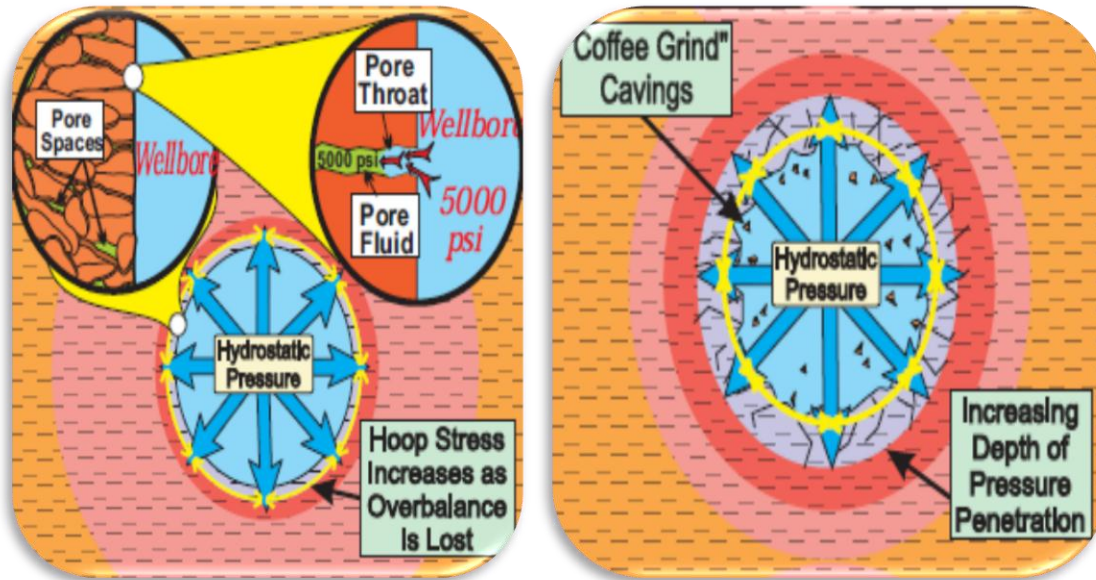
Well bore instability

Geo-pressurized shale

Curved splintery cavings on the shale shakers becomes blocky with the hole enlargement



Stuck pipe causes – Pack off/Bridge



Well bore instability

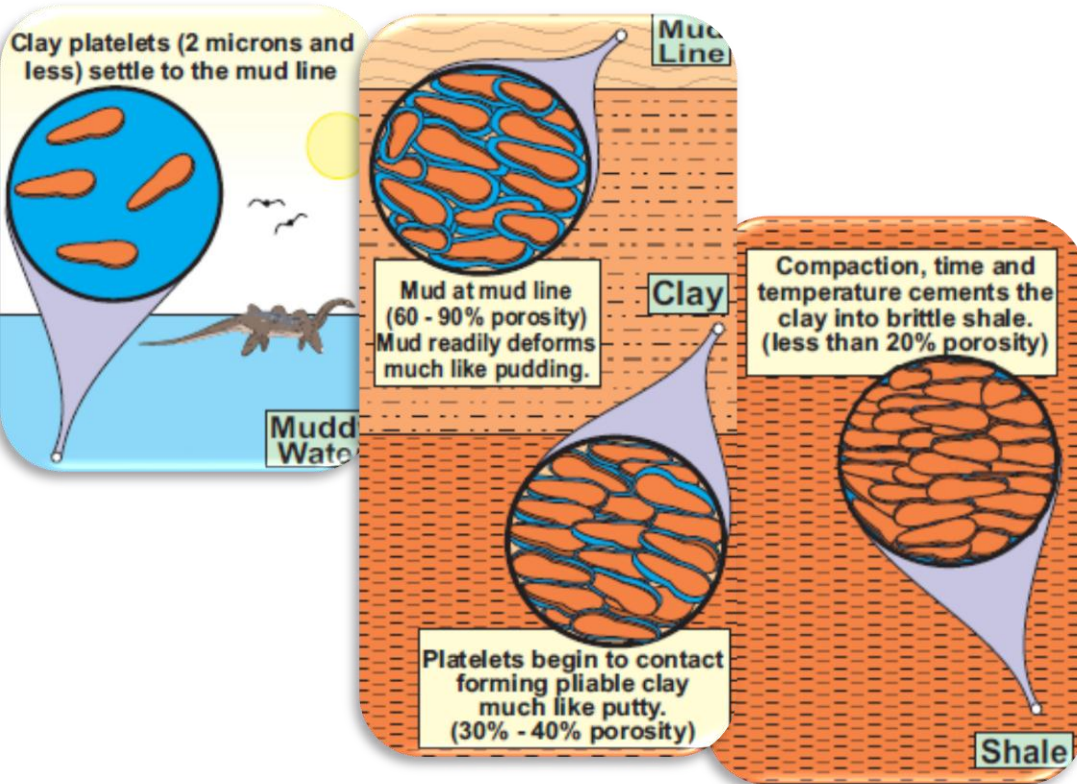
Hydro-charged shale

"Coffee grind" cavings over the shaker increasing to blocky cavings with longer exposure time

Prevention

- Use OBM.
- Plan to Minimize the Mwt as we

Stuck pipe causes – Pack off/Bridge

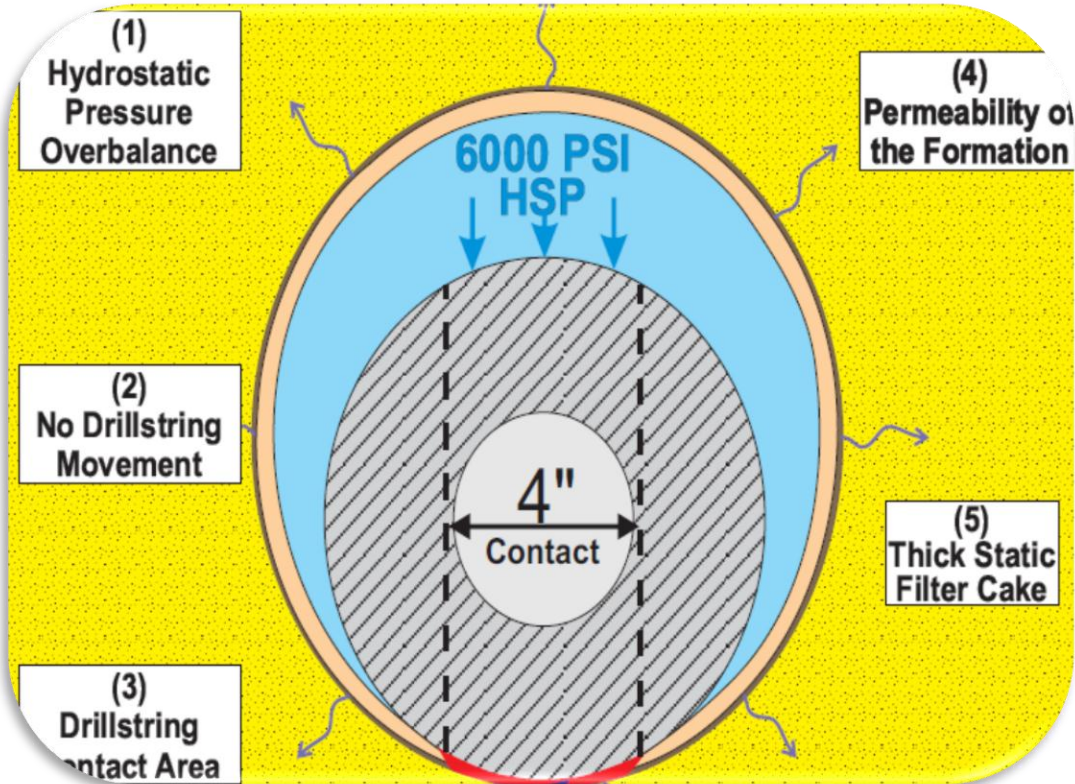


Well bore instability

Reactive shale

Reactive clay platelets attract and hold a layer of water (*adsorption*). The added water wedges between the platelets (*swelling stress*) and breaks the shale's natural cement bond. The brittle shale is reduced to ductile clay

Stuck pipe causes – Differential



Causes & prevention

Stuck pipe causes – Differential

Prevention

Minimize Overbalance Pressure:

Plan the casing setting depths to minimize high overbalance pressure at permeable zone depths.

Maintain the minimum mud weight required for well pressure control and wellbore stability.

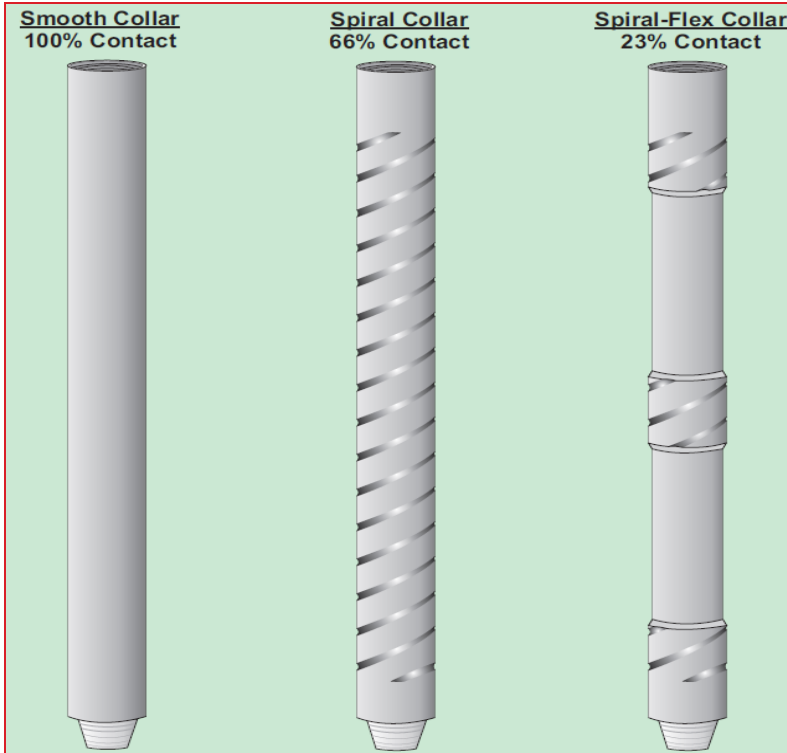
Control the rate of penetration to minimize mud weight and use proper hole cleaning practices.

Minimize Formation Permeability:

Use fine calcium carbonate to isolate wellbore pressure from low pressure permeable zones

until casing can be set. Add fine LCM to the mud system if seepage loss occurs.

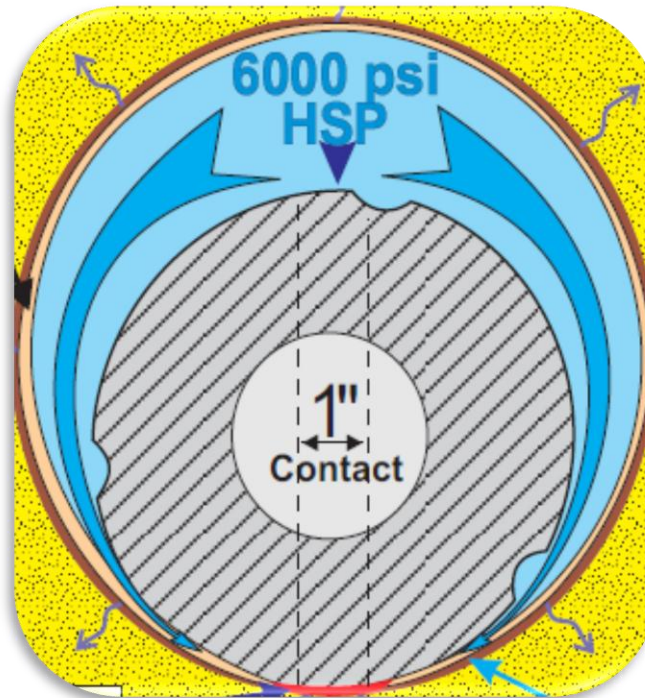
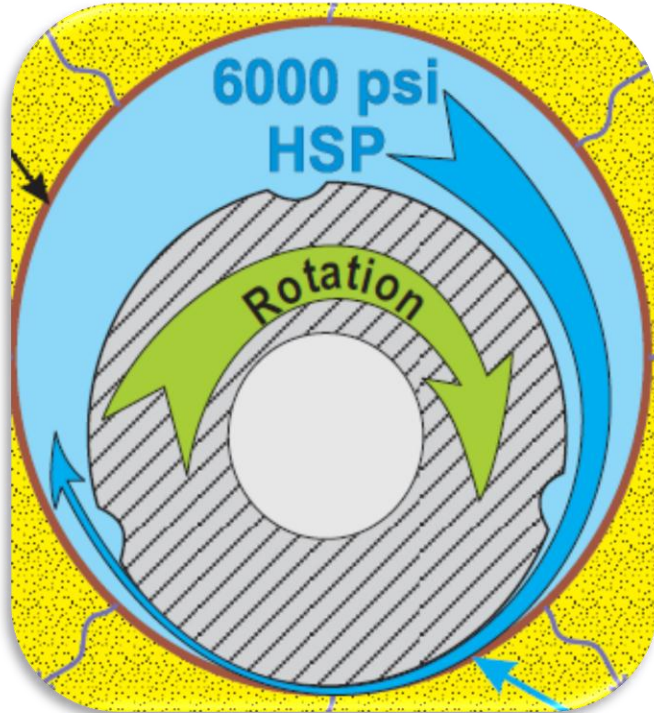
Stuck pipe causes – Differential



Causes & prevention

Contact area

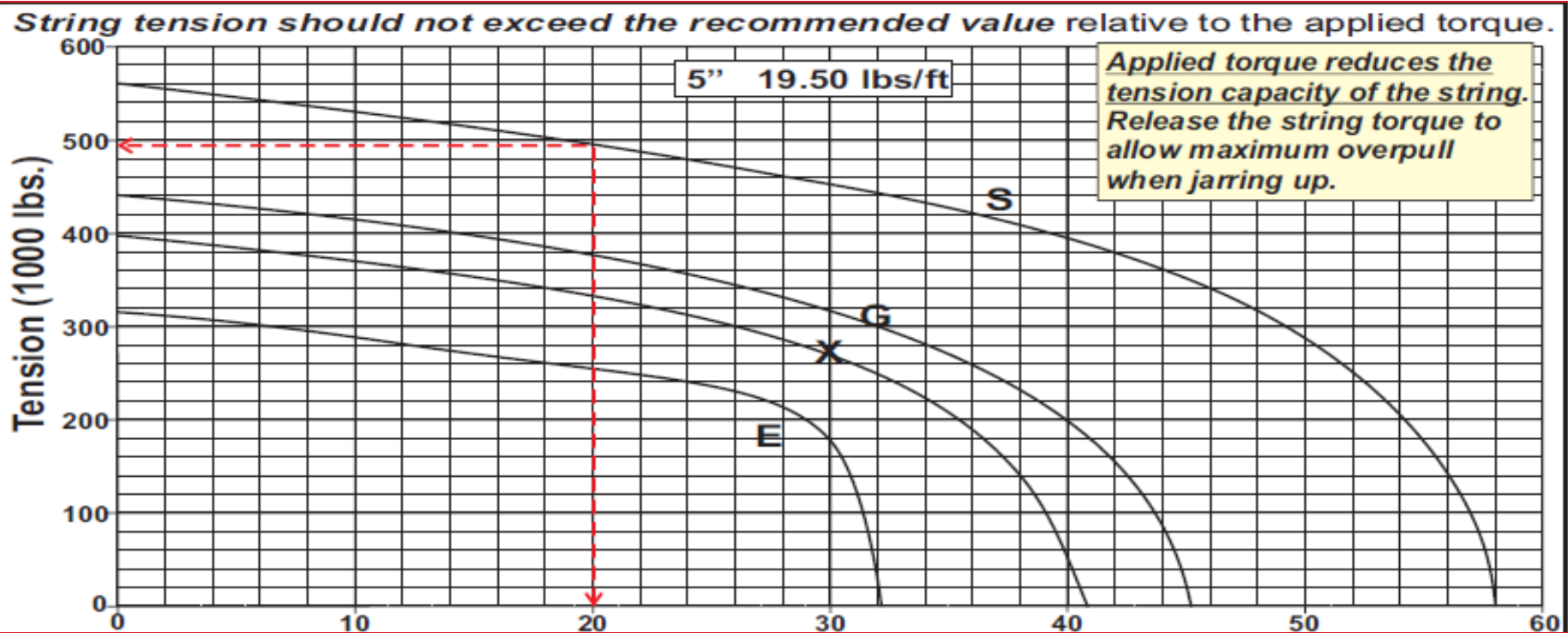
Stuck pipe causes – Differential



**Causes &
prevention**

Pipe Movement

Stuck pipe freeing – Differential



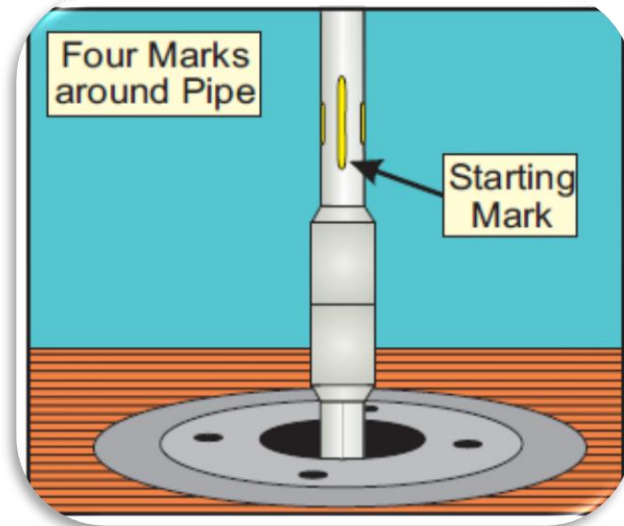
Stuck pipe freeing – Differential

Torque Factor For Size and Weight of Drillpipe					
Drillpipe	Lbs/Ft	Torq Fac	Drillpipe	Lbs/Ft	Torq Fac
2-3/8"	6.65	2.058	4-1/2"	16.60	19.221
				18.15	20.760
2-7/8"	8.35	3.848		20.00	23.023
	10.40	4.610	5"	19.50	28.538
3-1/2"	13.30	9.002		20.50	30.401
	15.50	10.232	5-1/2"	21.90	38.670
4"	14.00	12.915		24.70	43.141
	15.70	14.314	6-5/8"	22.20	56.284

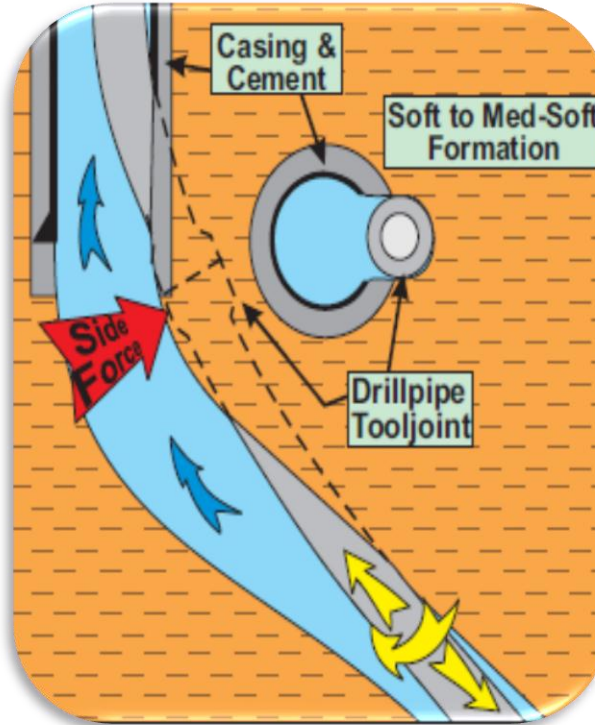
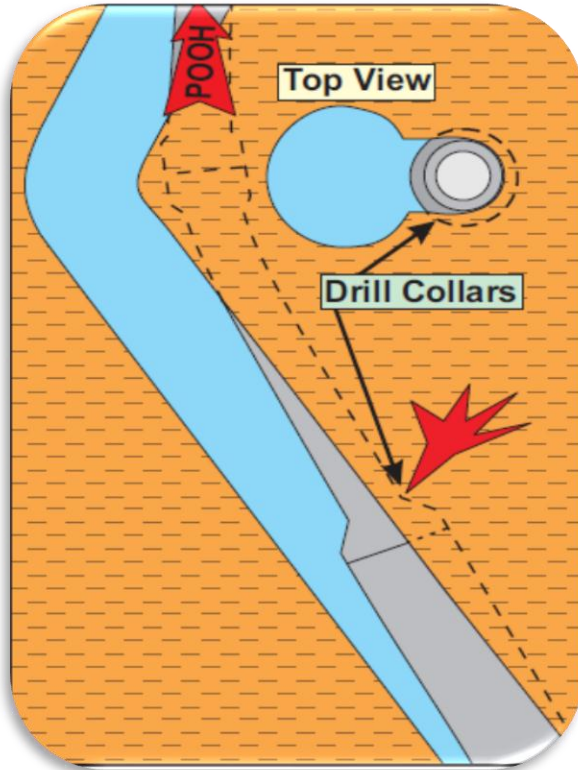
Calculate the Stuck Depth (Stuck_{FT}):

$$\text{Stuck}_{\text{FT}} = \frac{\text{Wraps} \times \text{Torq Fac} \times 501782}{\text{Applied Torq}}$$

Stuck depth calculation



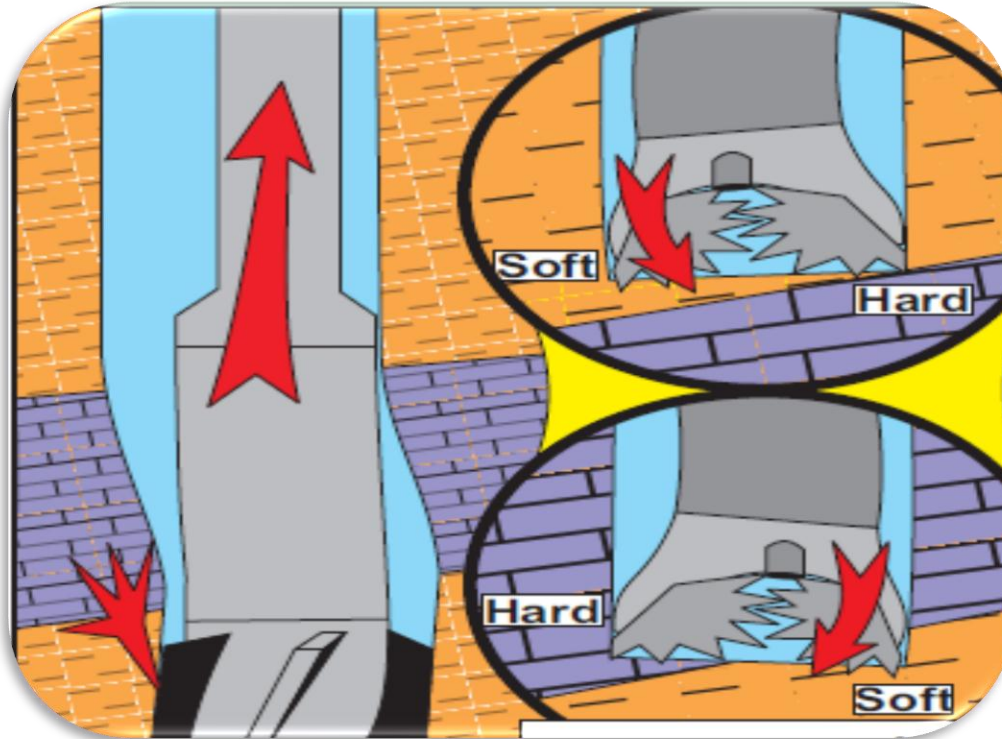
Stuck pipe – WB Geometry



Causes & prevention

Key seating

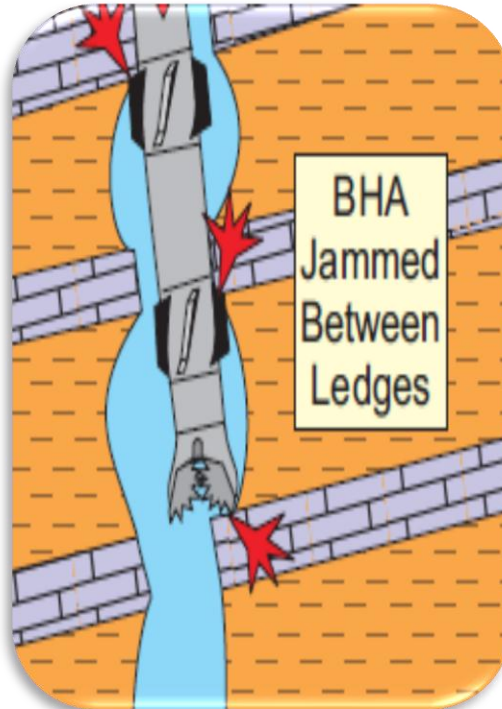
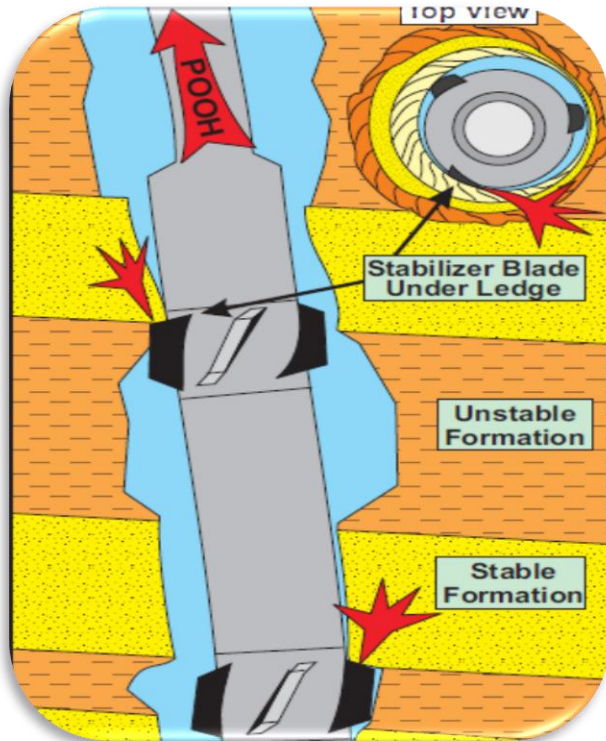
Stuck pipe – WB Geometry



**Causes &
prevention**

Micro doglegs

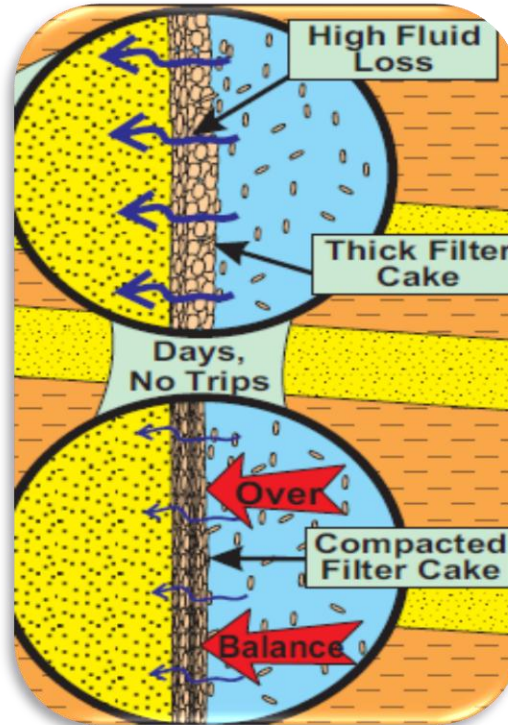
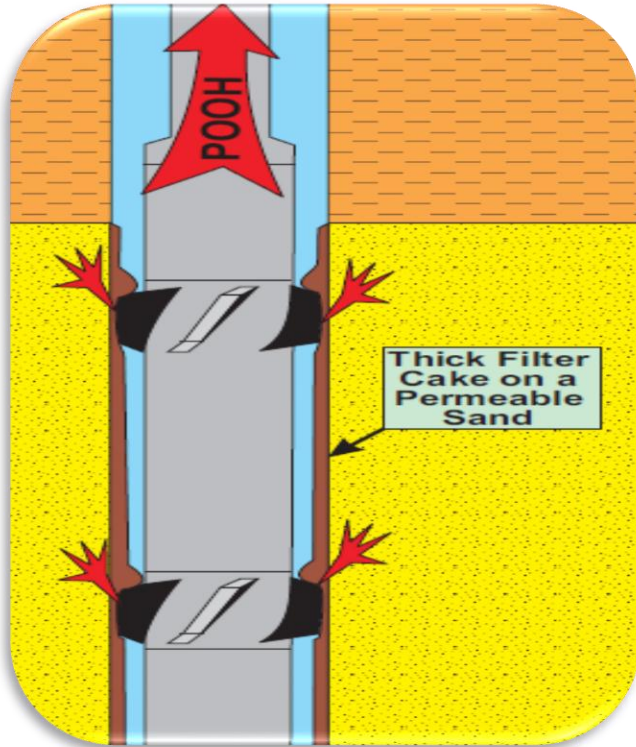
Stuck pipe – WB Geometry



**Causes &
prevention**

Ledges

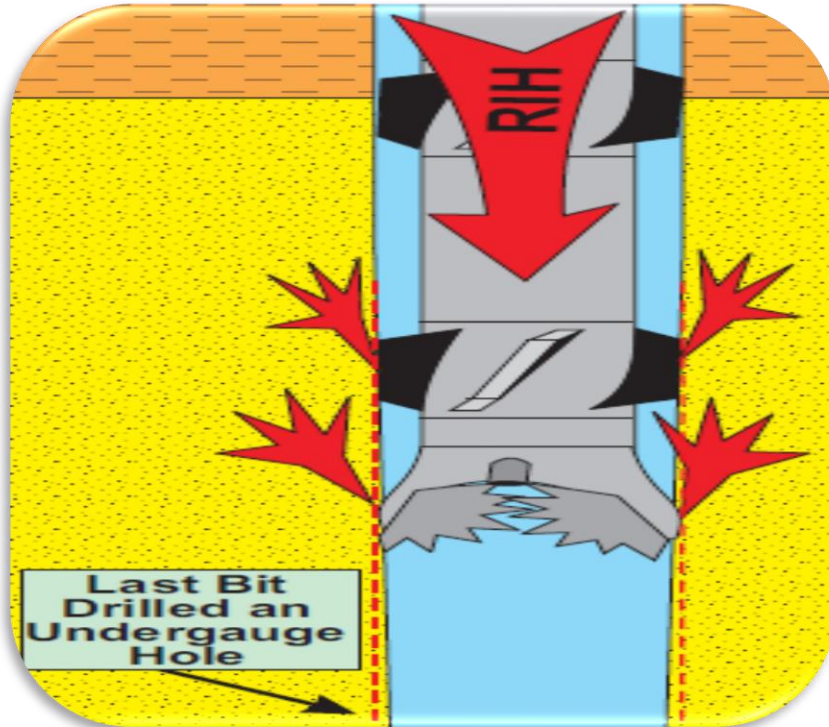
Stuck pipe – WB Geometry



**Causes &
prevention**

Thick filter cake

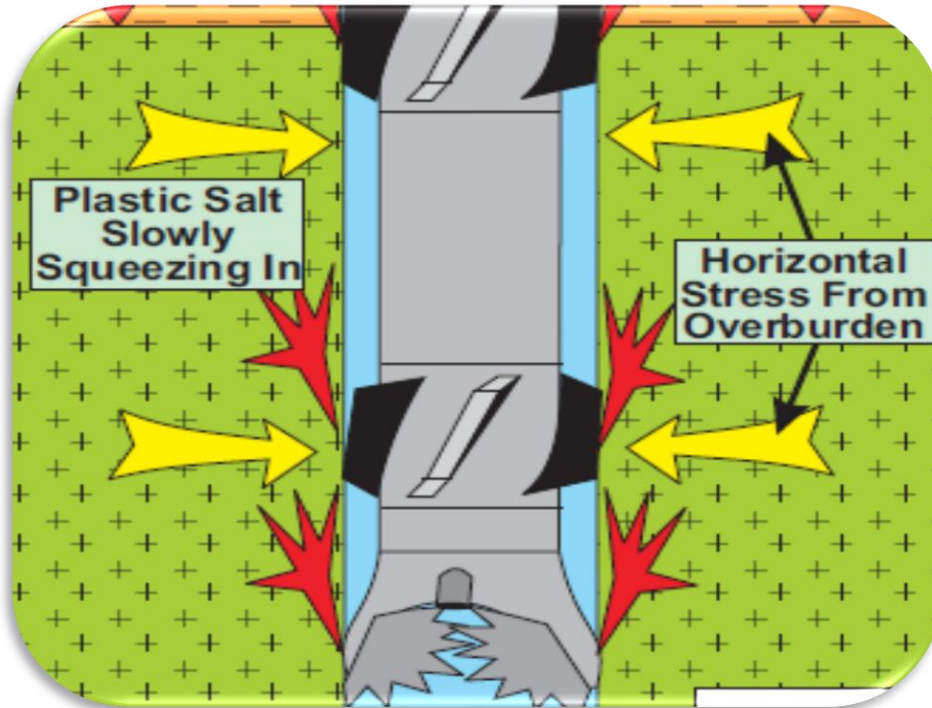
Stuck pipe – WB Geometry



**Causes &
prevention**

Undergauge hole

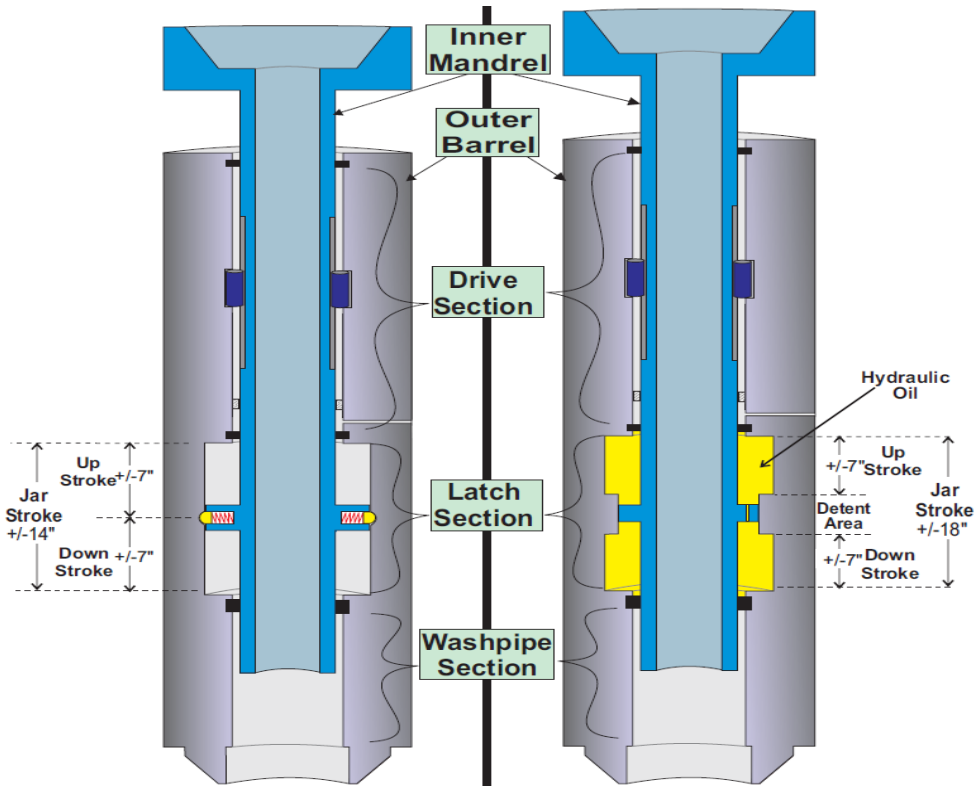
Stuck pipe – WB Geometry



**Causes &
prevention**

Mobile formation

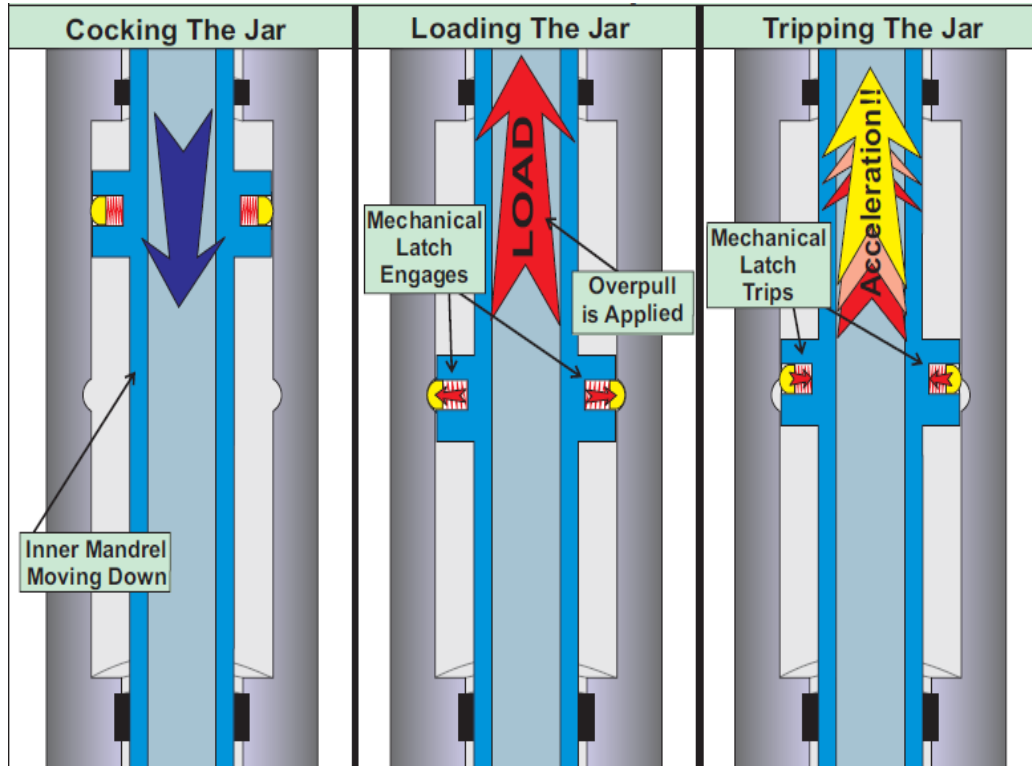
Stuck pipe – Jar & Accelerator



Drilling Jars

Jar types

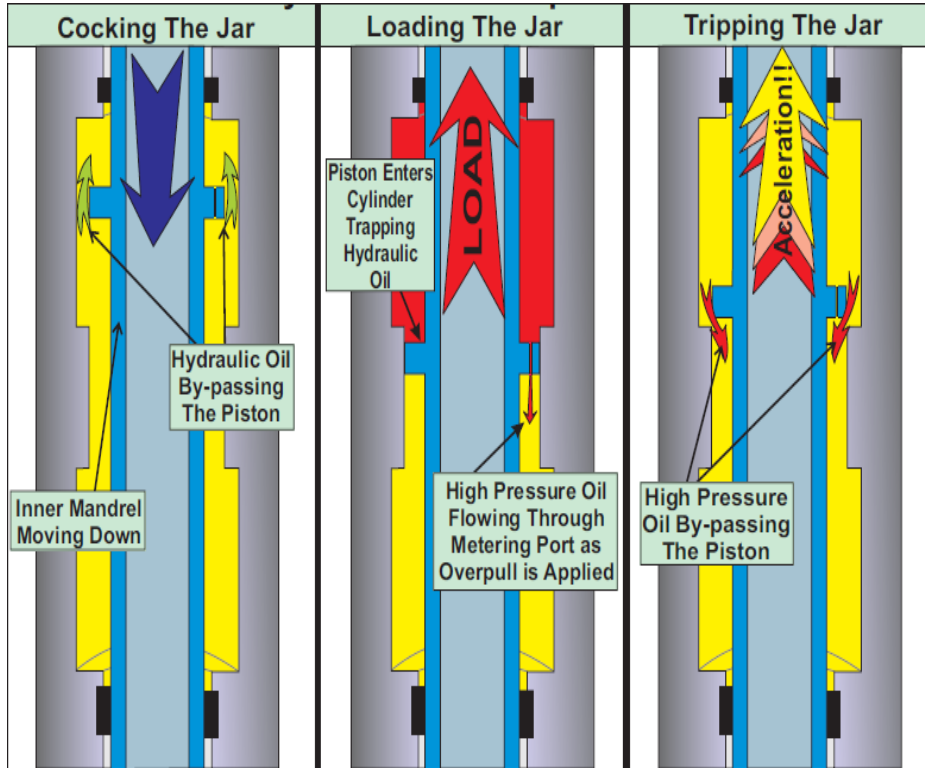
Stuck pipe – Jar & Accelerator



Drilling Jars

Mechanical jar

Stuck pipe – Jar & Accelerator



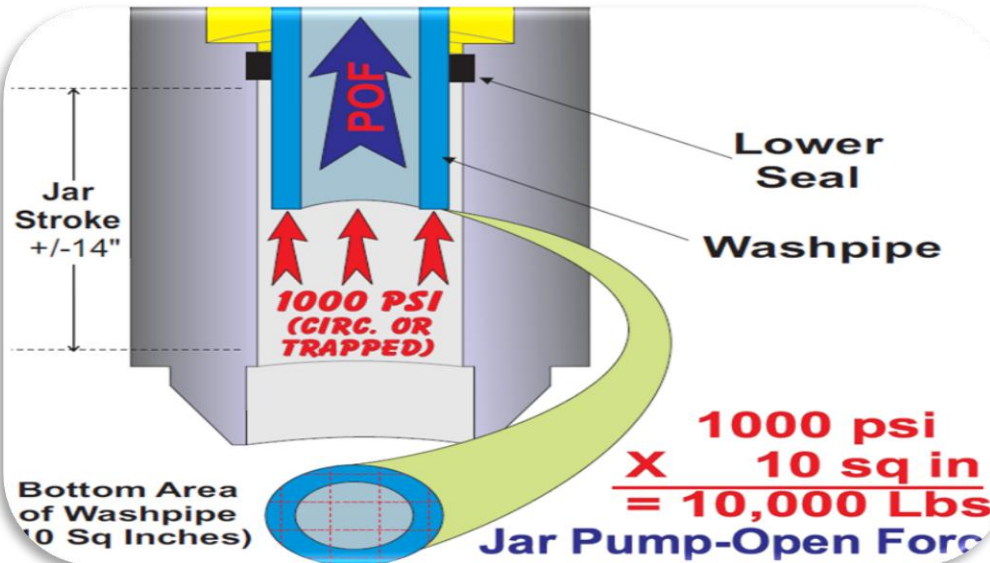
Drilling Jars

Hydraulic jar

Stuck pipe – Jar & Accelerator

Drilling Jars

Pump open force



Cocking from the Open Position:

More difficult to cock the jar.

Cocking From the Closed Position:

Easier to cock the jar.

Jarring Up: Intensifies the impact of the up-jar blow.

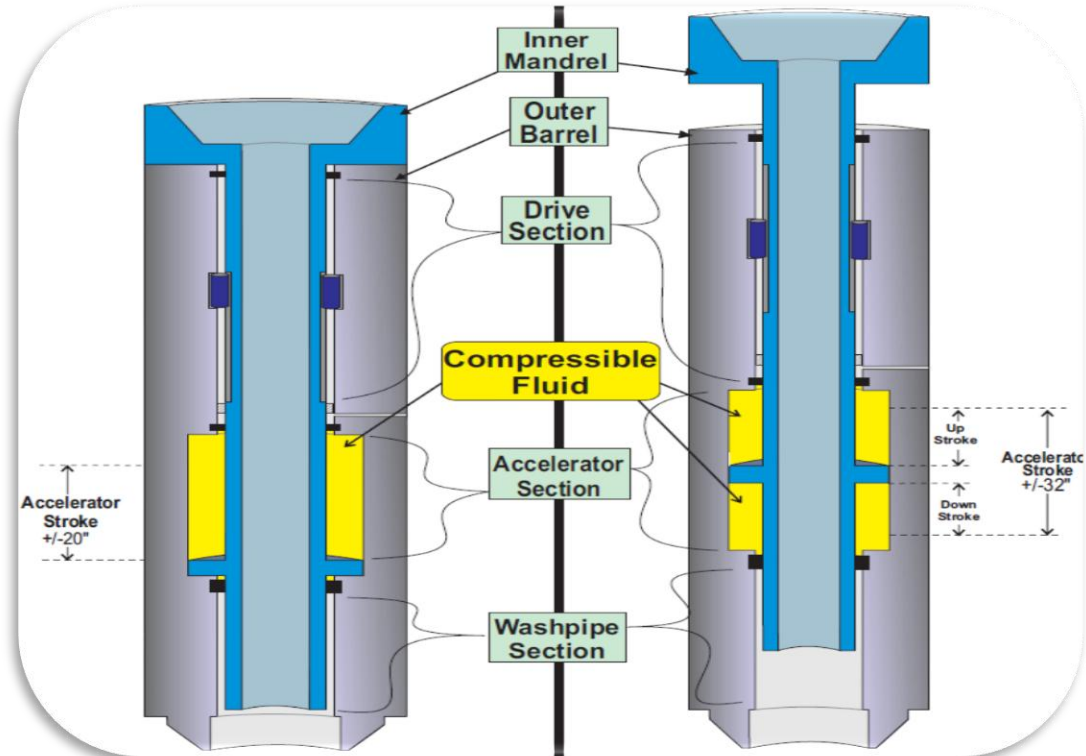
Jarring Down: Dampens the impact of the down-jar blow.

Bleed trapped pressure; stop or reduce pump speed when cocking the jar from the open position or when jarring down.

Stuck pipe – Jar & Accelerator

Drilling

Accelerators
Accelerators
types



Stuck pipe – Jar & Accelerator

Drilling Jars

Jar calculations

Cocking From Open Position	Cocking From Closed Position	Jar-Up	Jar-Down
Bleed trapped pressure / slow down or stop the pumps to make the jar easier to cock.			Bleed trapped pressure / slow down or stop the pumps when jarring down.
_____ Last Down Wt.	_____ Last Up Wt.	_____ Last Up Wt.	_____ Last Down Wt.
- _____ BHA Wt. Below Jar	- _____ BHA Wt. Below Jar	- _____ BHA Wt. Below Jar	- _____ BHA Wt. Below Jar
= _____ Wt Indicator Load	= _____ Wt Indicator Load	+ _____ Jar Trip Load	- _____ Jar Trip Load
		= _____ Wt Indicator Load	= _____ Wt Indicator Load
		The trip load of a hydraulic jar is selected by the operator	

Stuck pipe – Jar & Accelerator

Drilling Jars

Jar Notes

- Use the largest possible size of drilling jar in the BHA (will give the biggest impact)
- Do not place any stabilizers above the drilling jar. (You may become stuck at a stabilizer rendering the jar useless)
- Do not place the jar next to a stabilizer. (this is a point of higher bending stress)
- Have the same diameter tubular above and below the jar; ie the jar should not be at a transition between O.D. 's
- Have at least three drill collars or two stands of HWDP above the jar to act as an anvil
- Do not place the jar at or close to the neutral zone

Stuck pipe – Jar & Accelerator

Drilling Jars

Jar Notes

- Ensure that you and the driller know :
What kind of jars are in the string
The method of operation to jar up and down
How much pump open force to expect
- Consider the use of a jar intensifier (accelerator). It can improve jar impact force and double impulse. Place the intensifier one stand of HWDP above the jar